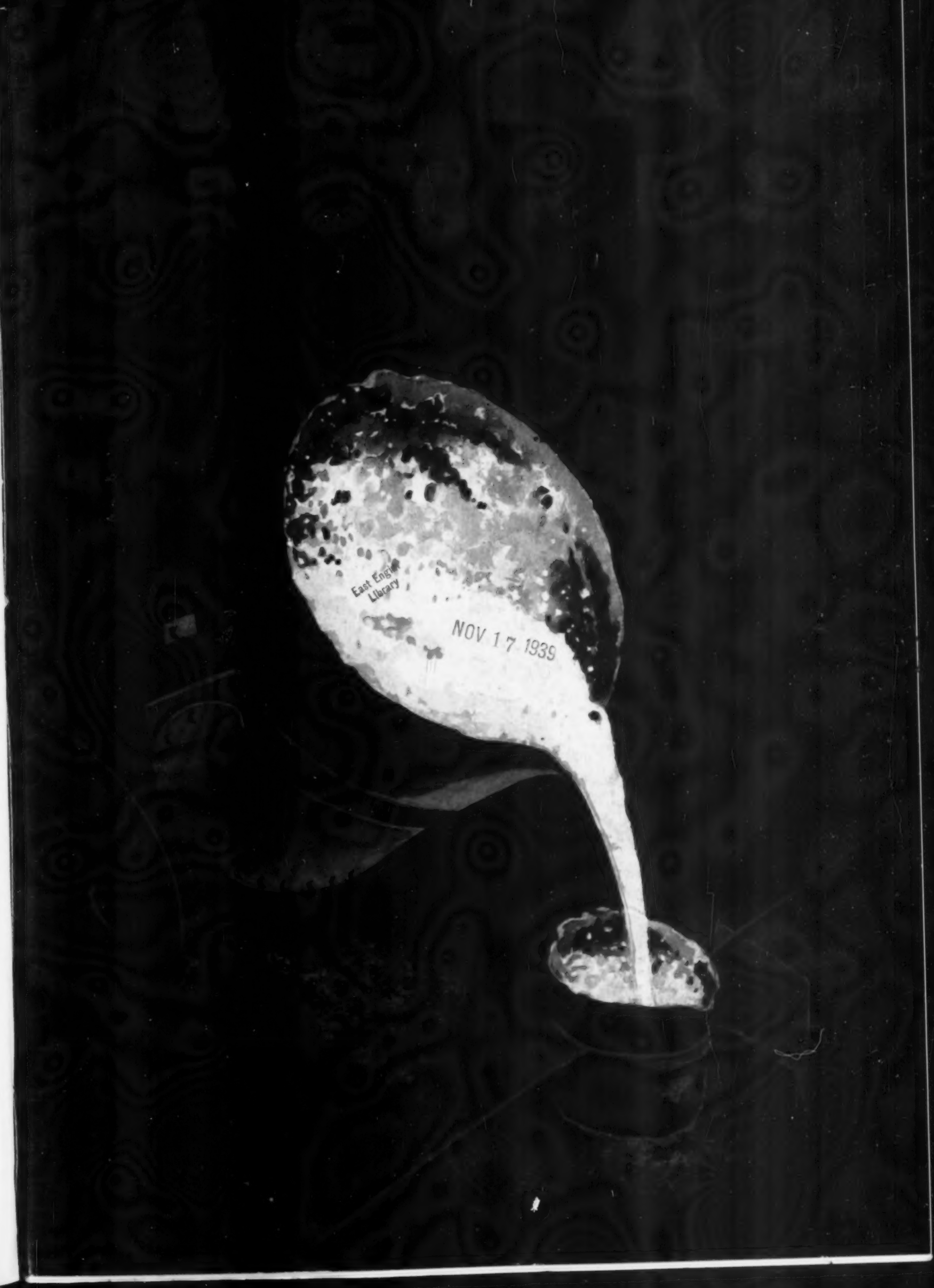
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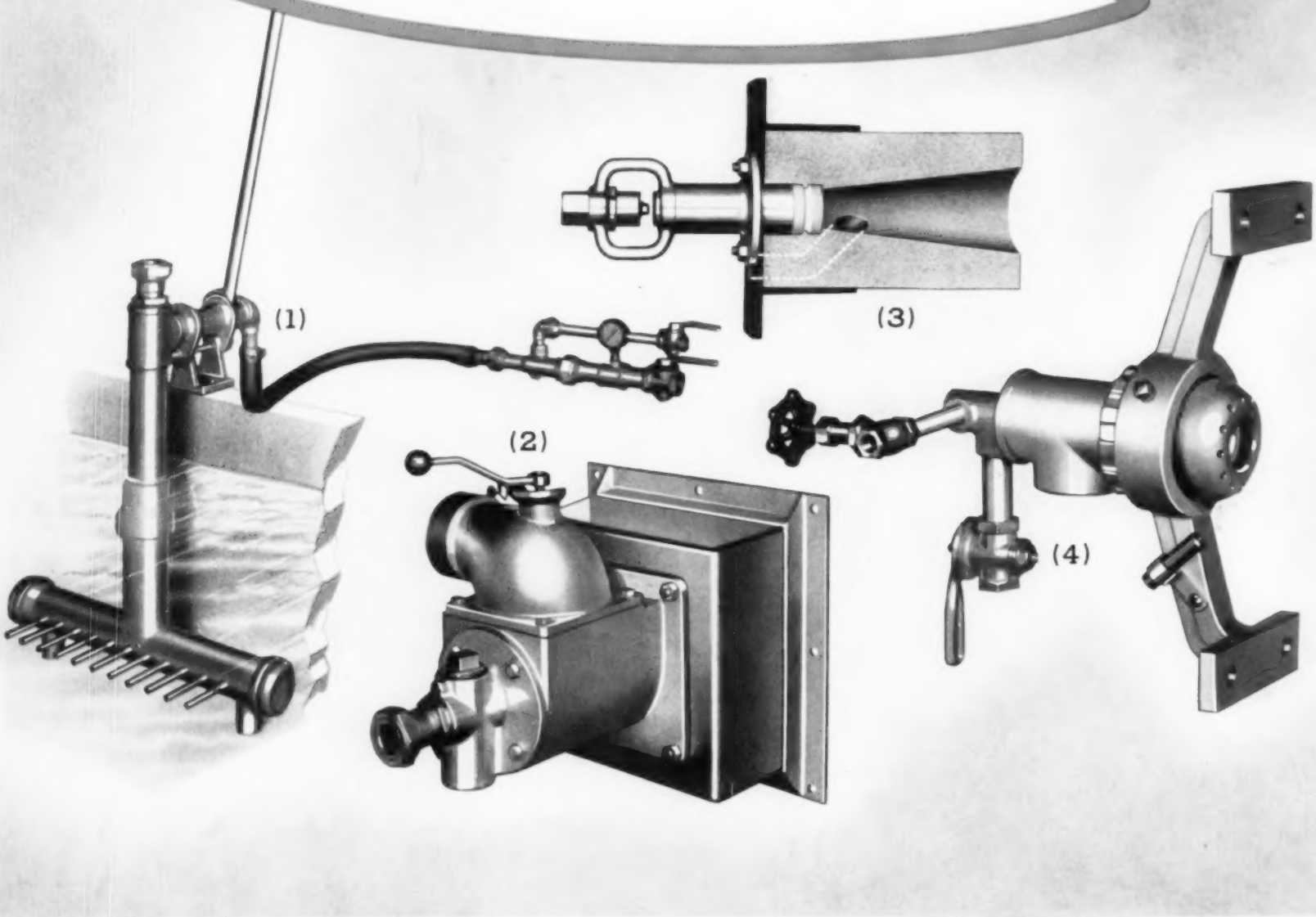

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Metal Progress

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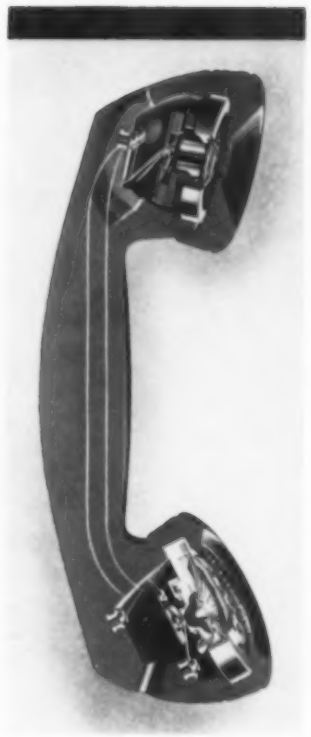
Metallic Materials . . . .

in the telephone system



By Earle E. Schumacher and W. C. Ellis*

ALEXANDER GRAHAM BELL gave the world the telephone, and the labors of thousands of scientists, engineers and workers from March 10, 1876 to the present have given us the telephone system of today. Its magnitude is emphasized by the fact that approximately 70,000,000 telephone conversations are handled daily. Each local call requires subscriber's equipment, a separate wire pathway, and switching equipment located at a central office. A large central office contains more than 4000 miles of wire and in the neighborhood of 2,500,000 electrical connections.

Electrical considerations are of paramount importance but metals and alloys have played a noteworthy part in the development of communications, since by its very nature telephone service requires an enormous amount of equipment consisting to a large extent of metallic materials. To emphasize this specifically, the handset serves as an admirable example. The assembly of intricate parts in this small piece of apparatus, shown sectionalized above, contains 17 metallic elements, either alone or in combination as alloys.

The Bell System has therefore conducted extensive metallurgical researches, and the discoveries and developments have been numerous. Space permits a brief discussion of only a few of the developments relating to the more extensively used materials. These comprise the alloys of lead, copper, zinc and aluminum, and the precious metals, and magnetic materials.

Lead and Alloys of Lead

Lead alloys are used principally as sheathing for cable, and as solders for joining cable sheath and making electrical connections in apparatus.

Cables represent one of the largest single items of investment; approximately 95% of the Bell System's total wire mileage is contained in lead or lead alloy sheath and this sheath requires an enormous amount of lead annually in its production. The largest size cable made by the System contains 4242 copper wires. The same number of open wires on telephone poles would take 70 rows of poles each carrying 60 wires. Under one street today in New York City there are 282 cables containing about 560,000 wires.

Since the wires in the cable are insulated from one another only by the paper or textile wrappings or sheaths and by the dry air contained in the cable, the presence of even a slight amount of moisture will interfere with trans-

*Bell Telephone Laboratories, New York, N. Y.

mission by drastically reducing the insulation resistance. A positive pressure of dry nitrogen is maintained in some cables as additional protection against moisture entrance and to disclose sheath breaks. Continued efforts are made therefore to improve cable sheath so as to reduce sheath failures to a minimum.

The history of cable sheath illustrates the value of research to the telephone system. Unalloyed lead was first used because it was pliable, resistant to corrosion and could easily be manufactured into pipe. Nevertheless, it has serious shortcomings. Brittleness would not be expected in a material so soft and ductile, yet repeated stresses caused by wind sway, mechanical vibrations and movements due to temperature changes produce fine cracks in the cable sheath through which moisture may enter the cable. An advanced stage of such cracking is shown in the view on page 621. In fact this effect is so serious that, unless precautions are taken to minimize vibration, cables sheathed with unalloyed lead cannot be shipped for long distances by rail or boat without serious damage.

It was early found that the addition of 3% of tin to lead greatly decreased the susceptibility to this type of failure. This alloy was also stronger than lead and more resistant to abrasion and the cutting action of the galvanized steel rings which usually fasten aerial cable to its supporting strand. As the quantity of alloy required for cable sheathing increased, however, it became evident that a large portion of the world's supply of tin would be needed, and this would cause a prohibitive rise in price. A search was made, therefore, for an alloy that would be at least equal in quality but would be less expensive.

As a result of investigation of the properties of 20 or more different alloys, an alloy of lead containing 1% antimony was selected, and this alloy was adopted in 1912 as the standard for Bell System use. Had the lead-tin alloy been continued as a sheathing material to the present time the cost would have been $25,000,000 greater (figured on the amount of cable sheath used during the intervening years and on the price of tin which actually prevailed during this time).

Standardization of lead with 1% antimony for cable sheath was not accomplished without the appearance and solution of many technical problems. For example, extrusion of sheath around the cable core has been an intermittent process, since the cylinder of the extrusion press is not large enough to contain sufficient lead to cover a full length of cable. It was necessary, therefore, to stop extrusion to recharge the cylinder with the molten lead alloy, which must weld to the previous charge — a slug of solid metal. If a layer of dross was present on the surface of this material remaining in the cylinder, a faulty weld was formed which would be subsequently extruded into the sheath. Also, during the recharging interval, the lead alloy remaining in the extrusion die received a different thermal treatment from that of the previously extruded sheath. Since the properties of the alloy are markedly affected by thermal treatment, there were frequently abrupt differences in stiffness of the sheath extruded just before and just after the charging interval. When this change in stiffness was sufficiently great, serious buckles occurred during reeling and installation of the cable.

Through a knowledge of the constitution and characteristics of the alloy, and by continual improvement in the extrusion process it has been possible to overcome obstacles such as these and to manufacture cable sheath of improved quality from the 1% antimony alloy.

The telephone metallurgist is also concerned with the life of the alloy in service. Many samples from sheath which has failed are examined annually and compared with samples from sheath which is giving satisfactory service. Microscopic examination in some instances reveals a clue to the causes producing early failure and thus suggests methods by which the failures may be eliminated.

In developing new alloys such as have been described and in studying the causes of failure of these alloys in service, extensive facilities are required. For example, Bell Telephone Laboratories possess an extrusion press for experimental studies and for the preparation of new cable sheath alloys. With this equipment commercial extrusion conditions can be investigated or, when desired, extrusion conditions can be varied to determine the effect on the properties of the alloy.

Microscopic and X-ray diffraction equipment are both extremely valuable in studying a great diversity of metal problems. For example, the possibilities of prolonging the life of cable sheath have been established through microscopic examination after a heat treatment consistent with the alloy structure. Again, the results of thermal treatment incident to the

soldering and repair operations on cable in the field can be observed and used as a guide to the value of certain procedures. An interesting example is concerned with the opening of splices in installed cable sheathed with lead-antimony alloy, a procedure frequently necessary. During aging in service the antimony-rich particles coalesce into relatively large lumps. When material in this condition is heated by pouring hot solder over the joint, pools of liquid are formed around each lump of antimony, and if an attempt is made to pry the sleeve of the splice open at once, the sleeve crumbles. If heating is prolonged a few minutes, however, the tiny antimony-rich liquid pools diffuse into the surrounding solid material; at this time the sleeve can be opened without injury.

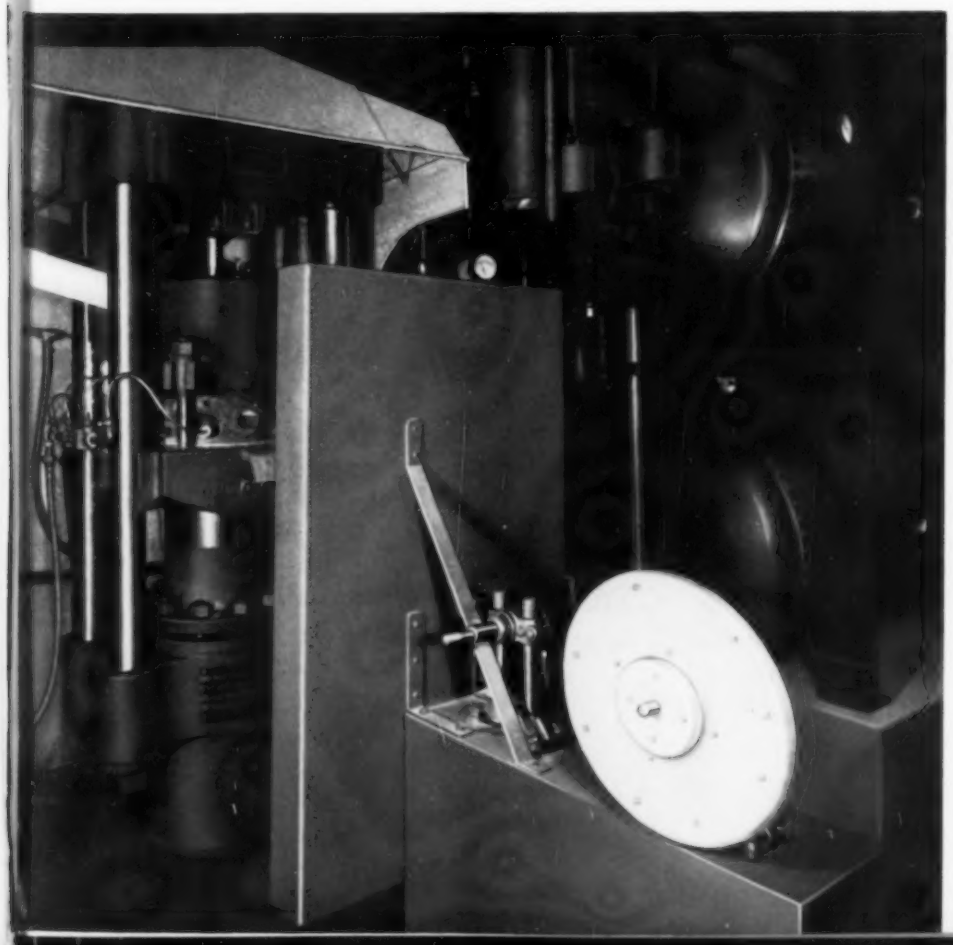
A few years ago, a new lead alloy containing 0.03 to 0.04% calcium was produced and is still being extensively studied for cable sheathing and other applications. Laboratory tests indicate that under some conditions this material excels lead-antimony in resistance to fatigue failure. To illustrate the careful consideration given the materials before making changes which might vitally affect telephone service, about 100 miles of cables sheathed with a lead-calcium alloy have been installed for a commercial field test. In addition, 36,000 ft. of experimental cable, sheathed with calcium-lead, were installed on poles alongside of similar lengths of cable with the standard sheath. Various sheath thicknesses ranging from 0.075 to the standard 0.125 in. were installed for comparison and to expedite early failure. In addition to the comparison between alloys this test will also give information regarding the minimum thickness of sheath which may be employed with both the standard and the experimental alloys.

Besides their application as cable sheathing materials, lead alloys are also extensively used by the Bell System for such purposes as solders, storage battery plates, fuses and as corrosion protection coatings.

Copper and Copper Alloys

Unalloyed copper finds application as wire in the lead-sheathed cables already discussed, in open wire circuits and in central office equipment. In the telephone plant there are 80,000,000 miles of it — enough to span the distance from the earth to the moon 335 times. To obtain the lowest transmission losses, cable conductors consist of high conductivity, annealed copper wire. For line wire in open wire circuits, hard drawn copper wire is used to take advantage of the conductivity of copper and the inherently greater strength resulting from strain hardening. Line wire is subject to ice and wind loads, vibration fatigue and, in some localities, severe corrosion. Where loading conditions are severe the copper-cadmium and other high conductivity, high strength materials have attractive possibilities but require further evaluation before they can be introduced into general use.

For drop wire — the conductor running from the telephone poles to subscribers' buildings — a material with somewhat different properties is required. Here lower conductivities can be tolerated but higher strengths are necessary since the wire is smaller in size and long spans are sometimes necessary. Several materials have been utilized. The alloy most generally in service is composed of 98.25% copper and 1.75% tin. This is being replaced now, as a result of



Extrusion Press and Associated Equipment Installed in Bell Telephone Laboratories for the Perfection of Manufacturing and Study of Cable Sheathing

research development, with a higher strength copper alloy containing 3% tin; gage can be reduced from 17 to 18 without sacrifice of necessary strength.

For most purposes ordinary electrolytic copper containing a fractional per cent of oxygen is satisfactory. There are some limited applications, however, where the copper is subjected to high temperatures in the presence of reducing atmospheres at some stage in the manufacturing process. Under these conditions, the presence of oxygen in the ordinary copper produces a well-known embrittling effect. For these applications a copper free from oxygen is used.

A small but important application of copper in telephone circuits is in the production of copper-oxide rectifiers. For this purpose a copper imported from Chile is ordinarily used; for some obscure reason domestic brands of copper have not generally proven as satisfactory.

Copper in the alloyed form also is used extensively in the telephone plant. One application, that for drop wire, has already been mentioned. Other extensive applications are for springs and contacting members in electrical circuits, and for structural parts where corrosion resistance or other desired physical properties justify their use. Copper-nickel-zinc (so-called "nickel silver") and to a lesser extent phosphor bronze, find application for springs. Brass is used primarily for wiper contacts since it lacks the desirable spring properties of "nickel silver" and bronze. Included in satisfactory spring requirements is long service life, which depends upon good fatigue characteristics and freedom — in many instances — from the tendency to season crack.

Die Casting Alloys

The demand in the Bell Telephone System for the economical production of large quantities of small complex parts has led to an extensive and growing use of die castings. If the past is a guide to the future, further expansion can be expected. Although the zinc base alloys represent the major proportion of all alloys consumed, other materials find application where specific properties are desired. High dimensional accuracy is obtained with tin base alloys; light weight is a notable property of aluminum base alloys. Lead base die castings are used principally in coin collectors where their sound deadening and mechanical damping characteristics are important. To produce the desired properties consistently the metallurgical characteristics of these materials must be known and specific procedures followed.

Electrical Contact Alloys

Requirements of a suitable contact are many, and vary with the use to which the contact is subjected. Two requirements that are universal and paramount are that the contact material must provide an electrical path of a low resistance and must not wear away too rapidly. (Some contacts are expected to give satisfactory performance for more than 150 million operations.) In the communication systems both precious and base metal contacts are extensively used. Of the former class, platinum, palladium, silver, platinum-gold-silver, gold-silver, palladium-copper, or platinum-iridium, have given good service performances. Wiping contacts are widely employed in dial central offices. These consist generally of brass and bronze, although silver is being used to an increasing extent.

Some idea of the extent to which our modern communication systems are dependent upon electrical contacts is illustrated by the number of pairs of precious metal contacts that must operate reliably to complete an ordinary dial system call between subscribers in a large city. This brings into operation about 300 relays, involving over 1000 pairs of contacts. In a long distance call between New York and San Francisco about 1500 additional pairs of precious metal contacts must perform dependably for satisfactory transmission. In some years our communication systems have required more than 100,000,000 pairs of contacts for the different kinds of telephone apparatus constructed or repaired.

It may be readily appreciated, therefore, that knowledge of the factors governing contact performance is of vital importance.

Magnetic Materials

Telephone apparatus presents a great diversity of applications for magnetic materials. Both "soft" and permanent magnet materials are extensively used. The soft magnetic materials — that is, those with relatively high permeability and low magnetic loss — are employed both as sheet and rod, and in a finely powdered form for compressing into cores for

inductance coils. Previous to 1920 the primary soft magnetic material was iron; small quantities of silicon steel also were used. Since that date a large number of new soft magnetic materials have been developed with superior properties for particular applications. The discovery of permanent magnet characteristics in dispersion-hardening iron alloys containing no intentional carbon has resulted in a number of materials with superior properties.

At this time, in the field of soft magnetic materials, iron and silicon steel find by far the most extensive application. The iron is a high grade commercial iron. The silicon steel used is the grade normally containing about 4% silicon. For applications requiring higher permeabilities and lower losses alloys of iron and nickel, known as the "Permalloys", are used. There are two principal Permalloys, one containing about 80% nickel and another 45%. The higher nickel composition is also modified by molybdenum or chromium additions to increase electrical resistivity and improve magnetic properties. Sheet and rod stock are used in relays, transformers, miscellaneous coils, and ringers.

View, About Half Size, of Piece of Old Cable Sheath Made of Commercially Pure Lead, Which Failed in Service From Intercrystalline Fracture

In investigating magnetic materials in the laboratory it is desirable frequently to fabricate the alloy into extremely thin sheet. The 20-roll cold-reduction mill shown on the next page is of value for this purpose. It is equipped with small diameter working rolls, each backed by a cluster of nine supporting rolls. With this arrangement high unit pressures are obtained and sheet a fraction of a mil thick can be produced readily.

In the form of 120-mesh powder and even in finer sizes certain of the Permalloys find application in loading coils, filter coils and associated equipment. To secure low losses the powder particles are each insulated with a high resistivity, heat resistant material prior to pressing into cores. Manufacture of this fine alloy powder is a unique metallurgical process, taking advantage of the effects of small amounts of added elements to achieve a desired result. The presence of a few thousandths per cent of sulphur in the iron-nickel alloys in the range of 80% nickel results in a structure which can be rolled to small section when hot, but when cold it is exceedingly brittle and can be pulverized to fine powder. The manganese content of the alloy must also be controlled since it has an effect opposite to that of sulphur.

The iron-cobalt system yields a useful magnetic material, the one containing approximately equal percentages of iron and cobalt. This alloy, called "Permendur", is characterized by high permeability at high flux densities and by a high reversible permeability when subjected to superposed direct-current magnetizing forces. The binary alloy cannot be fabricated cold and this appeared at first to limit seriously the applications for the otherwise promising material. Brittleness in cold rolling was overcome through the addition of approximately 2.5% vanadium, whereupon the alloy can be cold rolled after a quench from a high temperature. Fortunately the vanadium does not materially impair the useful magnetic characteristics. The alloy finds its chief application in the form of 0.010-in. sheet in the telephone receiver diaphragm.

Substantial tonnages of permanent magnet materials are also used in telephone apparatus every year. Of this most is 3.5% chromium and other permanent magnet steels of low cost and low maximum energy product (the B×H maximum for the demagnetization curve). Much of the remainder used is a material with high maximum energy product for receivers and other applications where space and weight limitations prevail. For this purpose 36% cobalt steel has been used but it is now replaced in new apparatus by an iron-cobalt-molybdenum alloy called "Remalloy", which has superior magnetic properties and is of lower cost.

This iron-cobalt-molybdenum alloy, which contains approximately 12% cobalt and 17% molybdenum, has no intentional carbon addition and is of a dispersion hardening type. The

hardening heat treatment consists of quenching from 2150 to 2375° F. in oil (after which the material is mechanically and magnetically soft) followed by aging at 1250° F. for one hour (which induces mechanical and magnetic hardness). The material can be hot-worked and machined except in the hardened condition, and welds readily, but is somewhat brittle.

Magnets of the iron-nickel-aluminum type are increasingly used in telephone apparatus. These alloys may be ternary compositions or may be modified by a number of additional elements; cobalt and copper additions have been found advantageous. The high coercive force, high maximum energy product, and light weight make them attractive. Disadvantages are non-workability and lack of machinability.

In addition to magnetic purposes, ferrous alloys are used extensively in other applications. Considerable quantities of carbon and alloy steels are used for structural purposes, and high alloy steels for installation and maintenance tools.

Prospective Developments

In concluding a discussion of metallic materials in telephone equipment interest naturally is directed toward the future developments. The trends in the use of new metallic materials in the telephone service are difficult to predict. A large class of applications includes the incorporation of improved materials in existing apparatus with some modification in design resulting in a cost saving or in improved service. Such materials originate from developments by the metallurgical industry or from investigation by the Bell System's engineers. Examples of this type have already been mentioned; for example, improved cable sheathing materials, electrical conductors, and magnetic alloys. This evolution in application of materials will undoubtedly continue and constitute a large part of the telephone metallurgists' activities.

There is another field of application for metallic materials, namely, applications in newly designed apparatus or systems of communication. Here the properties of existing materials are frequently inadequate to perform the required duties and new materials must be developed with the necessary properties. One example already cited is the preparation of magnetic powder for inductance coil cores. A new system of transmission, a million-cycle system, requires newly developed materials in the coaxial cable and the associated equipment. Special properties are usually involved which are of interest only in connection with communications, and hence the development of such materials is dependent almost wholly on the activities of the System's research groups.

Small, Precise, Cluster Mill for Rolling Thin Sheet Metals for Experimental Studies. As described briefly in Metal Progress, July 1939, each small work roll is backed up by an arrangement of nine rolls

Isothermal Transformation in steels . . . .

These extracts from the 1939 Campbell Memorial Lecture, delivered at the Chicago ASM convention last month, are limited to carbon, chromium and chromium-molybdenum steels. These steels were selected because the microstructure of the new "X" ferrite was shown for the highest alloy member of this series. The complete text, later to be published in *Transactions*, discusses many of the common alloy steels.

By Edmund S. Davenport*

IN RECENT YEARS it has become increasingly evident that if we are to get at the fundamentals of the subject of heat treatment of steel, we shall have to make a systematic effort to disentangle the influence of time and of temperature by studying each one separately.

Such considerations led us to investigate the constant-temperature or isothermal transformation of austenite. This work was started at the Research Laboratory of the United States Steel Corp. just ten years ago this month and has been pursued there continuously since that time. The so-called "S" curve diagram, which summarizes the observations in condensed form, is the theme of today's lecture; it depicts the time required for the break-down of austenite to ferrite and carbide at any constant temperature below the equilibrium transformation range and embodies, we believe, the fundamentals of the subject of heat treatment insofar as the transformation of austenite is concerned.

Several means for following the progress of isothermal transformation are available, for instance, by metallographic examination of specimens taken from a constant temperature bath at appropriate intervals, or by measurement of the change of length of a specimen at temperature, or even by hardness or magnetic measurements. Regardless of the method used, the data are usually plotted in the form of curves from which the time corresponding to any stage in the progress of the isothermal transformation may be estimated. The results of a series of observations at a sufficient number of temperature levels may be assembled on a single chart in which temperature of transformation is plotted vertically and time is plotted horizontally; smooth curves are drawn through the points representing the beginning and end of transformation at the different temperature levels and the result is the so-called "S" curve, [a typical example of which is given in the data sheet in last month's METAL PROGRESS, page 374].

Attention is called to two characteristic features of the "S" curve: *(a)* The two temperature regions of relatively *rapid* transformation, one in the range 900 to 1100° F. (the Ar′ region), the other at temperatures below about 200° F.; *(b)* the two temperature regions of relatively *slow* transformation, one just below the Ae_1 temperature, the other in the temperature range 300 to 800° F.

As would be expected, the mechanical

*Metallurgist, U. S. Steel Corp. Research Laboratory, Kearny, N. J.

properties of the products of isothermal transformation follow the trends of the microstructure; that is, as the transformation temperature decreases, the resulting structure becomes finer and finer and hardness and strength increase while ductility decreases. There is, however, a temperature range in which many steels fail to show the regular increase in hardness which might be expected from the corresponding decrease in transformation temperature. It is to be noted that this irregularity occurs in a temperature range corresponding approximately to the Ar′ range of the "S" curve which, in turn, coincides with a marked change in the character of the transformation product. Within this particular range, 800 to 1100° F., the microstructure changes from the lamellar or nodular to the acicular type; this is strongly suggestive of a fundamental change in the mode of transformation in this temperature range and there is ample evidence to support this view. A similar irregularity in the hardness curve occasionally appears in the *low* temperature range of rapid transformation, accompanying a change from the rapid-etching to the slow-etching acicular type of structure which, however, is not at all well-defined; further careful observations are needed to clarify this particular matter, and speculation seems somewhat beside the point until observations which can be interpreted unambiguously have been made.

The mechanical properties of the rapid-etching, acicular structure (bainite) resulting from isothermal transformation in the range 400 to 800° F. have been investigated in some detail, and the results have shown consistently that this structure, particularly in carbon steels, possesses an unexpected degree of toughness and ductility at relatively high levels of hardness (Rockwell C-50 to C-60). Extensive investigation of these facts led eventually to the development of a new method of heat treatment based upon isothermal transformation in this temperature range; this process is now commonly known as "austempering" and has been described in the technical literature.

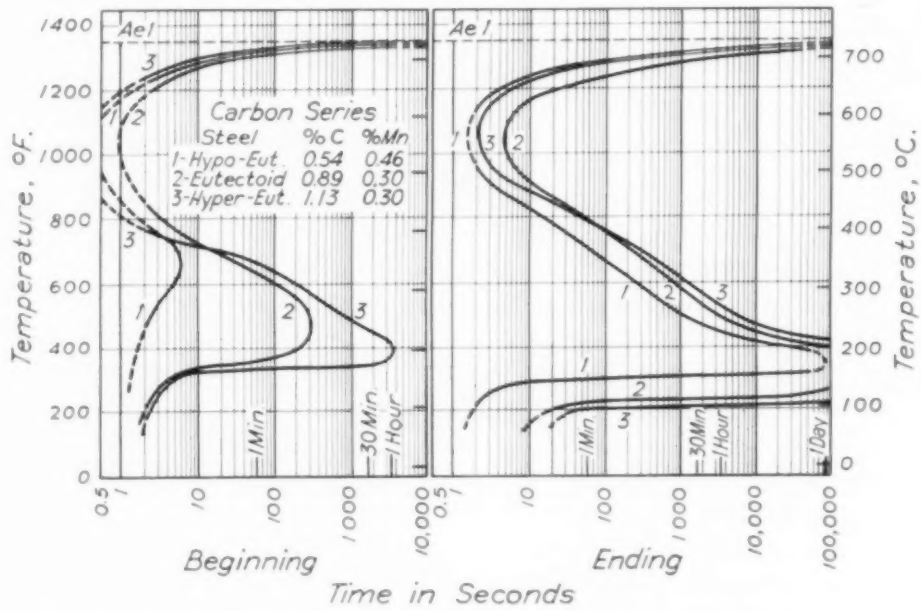
After approximately ten years of experience in this field it appears that the investigations of isothermal transformation have contributed to an improved understanding of the heat treatment of steel in at least four major ways, as follows:

1. They have provided us with a new, more comprehensive and clearer picture of the transformation of austenite, which in turn furnishes a new basis for a broad, general philosophy of heat treatment.

2. They have demonstrated the outstanding influence of the actual temperature of transformation on the character and properties of the several structures possible in a given steel, and on the essentially continuous variation producible in any single category of structures, such as the lamellar series (pearlite), or the acicular series (bainite or martensite).

3. They have permitted us to evaluate the influence of alloying elements on microstructure, mechanical properties, depth of hardening, and on many other criteria employed to judge the results of heat treatment.

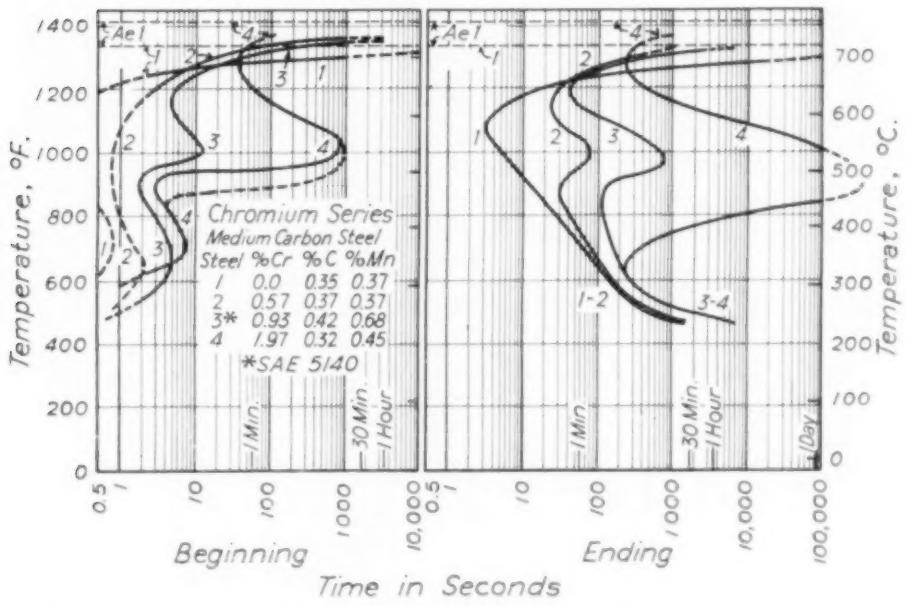
4. They have contributed to a rational explanation of the influence of coarser austenite grain size, which displaces the "S" curve in much the same manner as an alloying element displaces it.



Temperature-Time Curves Showing Beginning and End of Isothermal Transformation of Austenite in Three Plain Carbon Steels (Manganese and Other Elements Low and Within Narrow Limits)

Influence of Alloying Elements

In covering this aspect of the subject I shall first discuss the influence of certain individual elements — carbon, manganese, nickel, chromium, molybdenum, vanadium and cobalt — as revealed by isothermal transformation studies. Insofar as possible, the influence of each element will be demonstrated by means of comparison charts which show how the "S" curve is modified in shape and position as the content increases. To avoid a confusing multiplicity of curves on comparison charts for *hypo-eutectoid* steels, we have arbitrarily omitted the curve for beginning of pro-eutectoid ferrite separation at the higher temperature levels (Ar′ range and above) and have shown only the curves for beginning of formation of lamellar products (pearlite).

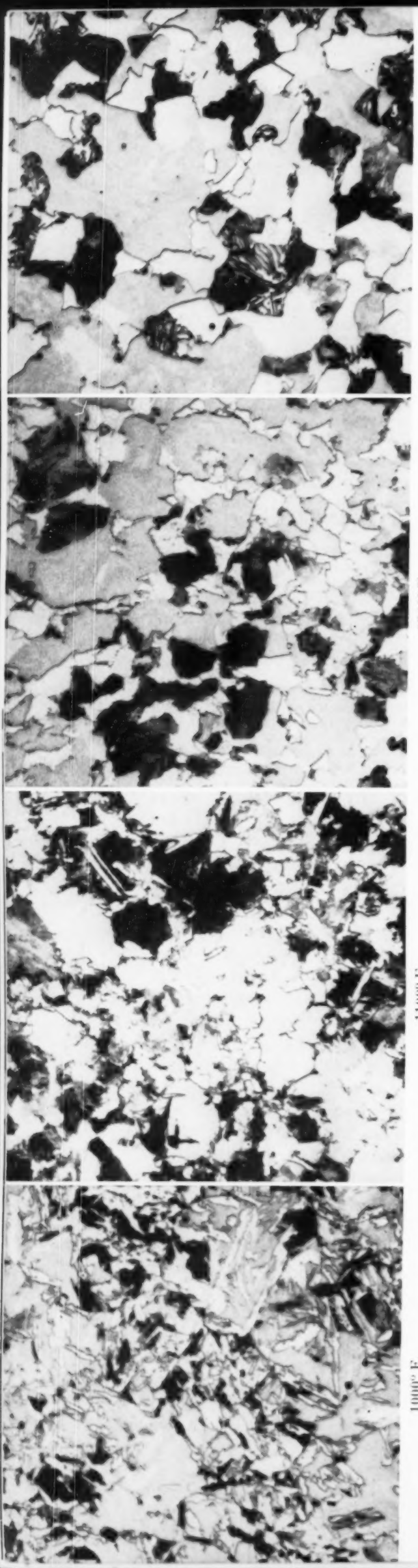


Temperature-Time Curves for Isothermal Transformation of Four Medium Carbon Steels Containing Increasing Amounts of Chromium. Chromium markedly slows down the transformation at Ar′

In these comparisons, austenite grain size, incidental elements, degree of solution of carbides and other factors which might influence the trends, were either held constant or maintained within narrow limits. In many cases only the portion in the vicinity of the Ar′ range is shown since this is the most significant part of the curve in ordinary heat treating.

Carbon — The first figure, page 624, shows the influence of carbon content as revealed by the "S" curves of three steels containing 0.54%, 0.89% and 1.13% carbon respectively, all with manganese in the range 0.30 to 0.45%. These curves indicate that the hyper-eutectoid steel (1.13% C) is the fastest of the three to start transforming in the Ar′ range; this behavior has been observed repeatedly and is probably associated with the rejection of pro-eutectoid carbide ahead of the formation of pearlite, these carbide particles then serving as nuclei which speed up the pearlite reaction. The curves for the hypo-eutectoid and eutectoid steels are in the same relation to each other in the Ar′ range as they are at lower temperature levels where the transformation is markedly and consistently retarded with increasing carbon content. Attention is called to the fact that the low carbon member of the series (0.54% C) begins to transform quite rapidly in the intermediate temperature range (400 to 700° F.), in which range the higher carbon steels behave very sluggishly; this effect will be even more evident when we come to the discussion of the 0.35 to 0.45% carbon steels of the alloy series. . . . .

Chromium — The influence of chromium in a series of steels containing 0.32 to 0.42% carbon is shown in the second diagram. In these lower carbon steels chromium is revealed as a very effective element for retarding the transformation in the Ar′ range, thus furnishing a rational explanation of the marked air hardening tendencies of many of the chromium-bearing steels. Note particularly the characteristic form imparted by chromium to the upper portion of the curves, and how this effect increases in intensity with increasing chromium content. The broken line in the curve for the 2% chromium steel represents what we believe to be the beginning of a second stage of transformation in this range of temperature; this point will be discussed in further detail in the last section. Note how the lower carbon content of these steels is reflected in the form of the beginning curve at the lower temperature levels, indicating that carbon is the element which largely determines the form and location of this portion of the beginning curve. The rather sur-



1300° F.

1200° F.

1100° F.

1000° F.

Microstructures on These Two Pages Represent S.A.E. 4140 (Chromium-Molybdenum) Steel, About Half Transformed at the Temperatures Indicated. 1000 ×. What appears to be acicular ferrite at 1000° F. has been called "X" constituent, for a fine precipitate tends to appear in it — as shown in micros on page 629

prising effects of alloying elements, as revealed by isothermal transformation diagrams such as those for the chromium steels, will become increasingly evident as the story continues, particularly when the S.A.E. steels are taken up for discussion. . . .

Curves for S.A.E. 4140 Alloy Steels

Turning now to the influence of alloying elements as revealed by the isothermal transformation curves of some typical, commercial S.A.E. alloy steels of the 0.35 to 0.45% carbon grade, let us first consider the diagrams for the individual steels. The curves were determined both by the metallographic and dilatometric methods at about 100° F. intervals down to 400 or 500° F.; within the limits of experimental error, the results obtained by the two methods checked remarkably well.

In general, a heating temperature comparable with that used in commercial practice was employed in working out the isothermal transformation diagrams of these steels; this was done in order that the data obtained might be as practically useful as possible, even though, in some instances, it meant that the full alloy content of the steel was not in solid solution in the austenite. All the steels were given a preliminary normalizing treatment consisting of air cooling from 1800° F. in the form of 1 to $1\frac{3}{8}$-in. rounds.

The isothermal transformation curves tell their own story more eloquently than any words could, and only brief comment will be made on the more important features. Full appreciation of the peculiarities of these S.A.E. steel curves can best be had by frequent comparison with the "S" curve for eutectoid carbon steel and with those showing the influence of individual alloying elements presented earlier. Since only one steel is dealt with on the chart on page 628, it is possible to show the line for beginning of pro-eutectoid ferrite rejection (as well as the line for beginning of formation of lamellar product) at the higher temperature levels; thus the relationship of these two lines to the Ae_3 and Ae_1 temperatures respectively is clearly brought out. The Rockwell C hardness obtained after complete transformation at the different temperature levels is also indicated.

As the discussion of the S.A.E. steel curves proceeds, it may be helpful to regard the diagram as a kind of map in which the region between beginning and end of transformation to the "ferrite-carbide" aggregate corresponds to land, and the regions on either side to water; thus the water on the left would be the "austenite sea" and that on the right the "ferrite plus carbide sea". Following out this simile, we shall have occasion to refer to "bays" and "promontories" in discussing some of the peculiar features of these rather strange-looking curves. The series of X's appearing between the ranges for lamellar and acicular products of transformation represents an intermediate type of

structure which will be discussed in a subsequent section of the present lecture.

Attention is also directed to a convention used for representing the end of transformation at the lower temperature levels, 500 to 600° F. and below. The curve labeled "Transformation Ends" represents, as well as could be determined experimentally, what we believe to be the true (100%) end of transformation at these temperatures. Note that this line extends out to extremely long time periods, an observation which is consistent with the well-known tendency of many of these alloy steels to retain some proportion of austenite permanently at room temperature. Another curve, labeled "Virtual Ending", represents the approximate time for the transformation to go to substantial completion; this time is, in most instances, of greater practical significance than the time for complete transformation of every last trace of austenite at these low temperature levels. . . . .

The curves on page 628 for S.A.E. 4140 (0.80 to 1.10% Cr; 0.15 to 0.25% Mo), as compared to the curves for S.A.E. 5140 of similar chromium content, show that this combination of chromium and molybdenum results in a pronounced alteration in the shape and location of both the beginning and ending curves at the higher temperature levels. It is to be noted that this steel is most sluggish in its isothermal transformation behavior. . . . .

Hardness of Transformation Products

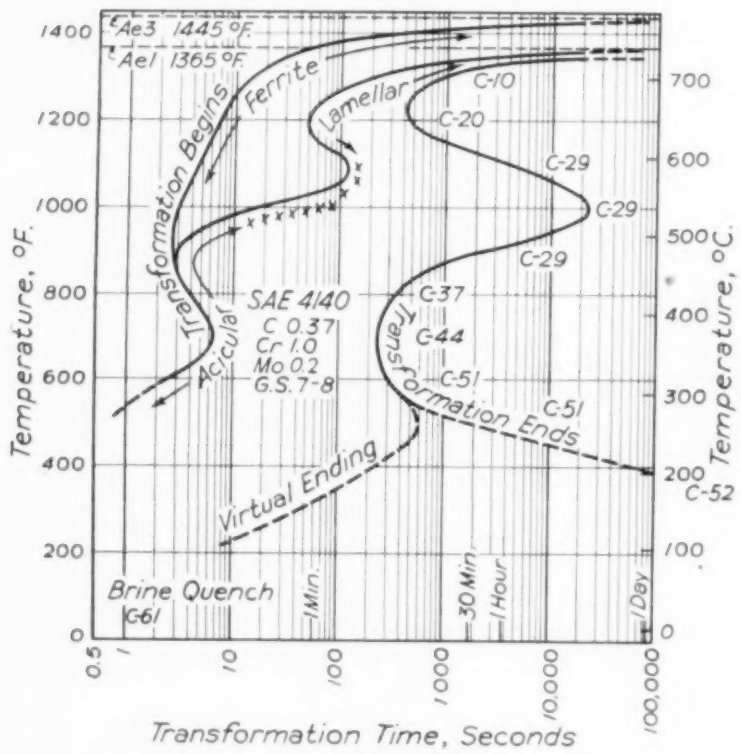
The Rockwell C hardness of the products of isothermal transformation of the S.A.E. steels shows an irregularity in the range 900 to 1100° F., much the same as the corresponding curves for carbon steels. The effect is particularly marked in steels containing strong carbide-forming elements such as chromium, molybdenum and vanadium. Reference to the isothermal transformation curves of the S.A.E. 4140 steel [the third diagram, page 628] shows that this irregularity in the sequence of hardness with transformation temperature tends to be associated most closely with the temperature range in which the structure changes from the lamellar to the acicular type. Incidentally this occurs in the same general temperature range as the curious bay and promontory effects in the beginning and ending curves respectively. We believe that this is a manifestation of a fundamental behavior, common to both carbon and alloy steels, and further reference will be made to the question when the subject of microstructure is discussed presently. . . . .

Microstructure of S.A.E. Steels

It is obviously impossible to present here an adequate discussion of the microstructures encountered in this investigation of the isothermal transformation of S.A.E. steels. In general, the same basic trends are found in these steels as in carbon steels [see the August 1935 issue of METAL PROGRESS]; a series of lamellar structures is formed at the higher transformation temperatures, while acicular structures are formed at lower levels. In most of these steels, the intermediate temperature range yields structures which do not fit readily into the present scheme

of metallographic nomenclature; moreover, there are differences in the structure of the different steels at the same temperature level and it is in the intermediate temperature range that these differences seem to be most pronounced. A sizable volume could be written about this without beginning to exhaust its possibilities.

As a compromise, we have elected to show the structures encountered at the different temperature levels in the S.A.E. 4140 steel as being fairly representative of most of the S.A.E. steels investigated. As a further limitation, we will show only the structure obtained at certain temperature levels when the steel is about half



Complete Transformation of Medium Carbon Chromium-Molybdenum Steel of Grain Size 7 to 8 (S.A.E. 4140) Requires a Very Long Time at Any Temperature Above 400° F. A new microstructure appears at x-x-x

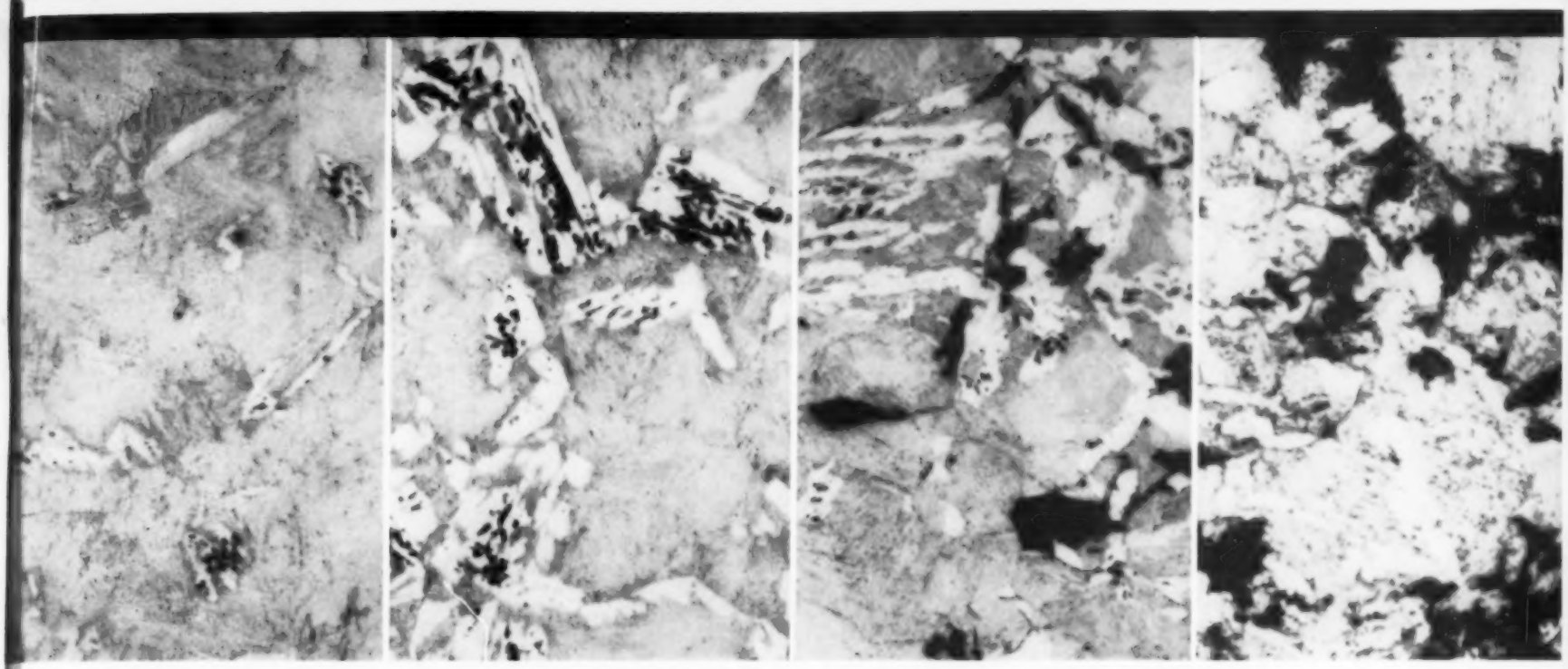
transformed, since at this stage of the reaction both the mechanism of the transformation and the nature of the product can be most easily seen. These structures are shown on pages 626 and 627 at 1000 diameters.

At 1350° F. the product of transformation consists of chunky pro-eutectoid ferrite and coarse, lamellar pearlite. As the transformation temperature is decreased to 1300 and 1200° F., the ferrite [white areas] continues to be chunky, although decreasing somewhat in volume and tending to outline the austenite grain size more clearly; at the same time, the pearlite becomes increasingly finer and more nodular as the transformation temperature is lowered. [The grayish, half-tone areas covering about half of these two micros represent austenite at the time of final quench.] At 1100° F. the ferrite decreases still further in volume and begins to show an acicular or Widmanstätten type of distribution, while the rapid-etching ferrite-carbide product (pearlite?) is now practically unresolvable and even begins, itself, to show a slight acicular tendency.

At about 1000° F. the rapid-etching product appears quite acicular and, strangely enough, there is an unexpected increase in the volume of pro-eutectoid ferrite (if such it be), the distribution of which is distinctly acicular or Widmanstätten in character. In most of the alloy steels, particularly those rich in the carbide-forming elements, this acicular ferrite (?) which we have provisionally designated as "X", soon takes on a speckled appearance as though something were precipitating in it with increased holding time at temperature. This suggests that it may not be pro-eutectoid ferrite in the ordinary sense of the term, but rather some form of high temperature acicular product (bainite) which is reluctant to precipitate its carbon until an appreciable period of time has elapsed. It is worth noting that these particular structural effects occur at about the same temperature level as the bay in the beginning curve and the promontory in the ending curve which, in turn, seem to be associated with the irregularity in the sequence of hardness with transformation temperature. All of these phenomena undoubtedly are intimately related and continued study should reveal their fundamental and practical significance.

At 900° F. and at lower temperatures the acicular ferrite ("X") observed in the vicinity of 1000° F. disappears entirely and the transformation product becomes more rapid-etching and more acicular in character much in accordance with the behavior of carbon steels. The transition zone between lamellar and acicular products is indicated on the isothermal transformation diagram of the S.A.E. 4140 steel by a series of X's, and for the present, we are inclined to leave this structure unnamed until its true nature is revealed.

One more item in connection with this



Stages in the Isothermal Transformation of S.A.E. 4340 (Nickel-Chromium-Molybdenum) at 900° F. 2000 ×. At left is beginning of first stage of transformation. In the next, considerable quantities of constituent "X" (white, like ferrite) have appeared and a precipitate formed freely in most of these grains. The right two micros show, respectively, the beginning and later development of the second stage in the transformation of the remainder of the metal into an acicular product similar in appearance to the bainite of carbon steels

transition zone and the microstructure formed therein may be worth mentioning before leaving the subject. It has to do particularly with the mechanism of transformation at temperatures just below the "shelf" in the isothermal transformation curves of steels relatively high in carbide-forming elements, such as the 2% chromium steel at about 950° F. [see the diagram on page 625]. Careful observations lead us to the tentative conclusion that the transformation proceeds in two fairly distinct stages in this temperature range, in a manner somewhat analogous to the two-stage behavior (first ferrite, followed by pearlite) characteristic of higher temperature levels. The first stage consists of the separation of acicular or Widmanstätten type ferrite ("X") which presently undergoes some sort of precipitation reaction, giving it the speckled appearance; then, when this stage is completed, the remainder of the transformation proceeds by the acicular process which yields a rapid-etching product similar in appearance to the familiar bainite of carbon steels. The above series of photomicrographs illustrate these two stages in the transformation of S.A.E. 4340 steel at 900° F.; the first two micrographs show examples in the first stage, in which only speckled ferrite ("X") appears, while the others are in the second stage, in which rapid-etching bainite is beginning to appear. This two-stage behavior is indicated on the isothermal transformation curves for the 2% chromium and 4340 steels by a dotted line beneath the "shelf" at 950° F., representing the beginning of the second stage of the reaction. We suspect that a similar state of affairs exists in many of the alloy steels but have been unable, so far, to determine it with sufficient precision to warrant indicating this behavior on the isothermal transformation diagrams.

Conclusion

By placing the isothermal transformation diagrams of typical alloy steels in the record at this time, it is hoped that greater interest in this approach to the subject will be aroused and that more widespread familiarity with these diagrams will result in clarification of some of the new questions posed by them.

Some of these questions center around *why* certain elements, or combinations of elements, alter the shape of the curves as they do, and what we may hope to be able to do in the future in the way of selecting alloy combinations to yield specific and predictable results. Other questions have more to do with the mode of transformation and *how* the mechanism by which a given structure forms out of austenite may influence its physical properties. Still other questions deal with the relationship between isothermal and continuous cooling transformation diagrams, a subject merely mentioned in passing today, but one which is of paramount importance in applying isothermal transformation data to practical heat treating.

A YANKEE ENGINEER AND METALLURGIST

Stanley Pickett Rockwell

recipient of

ALBERT SAUVEUR ACHIEVEMENT AWARD, 1939

THE DECADE prior to the World War was the beginning of a new industrial era, an era which demanded better technical control of industrial products, and it was in the beginning of this new era that Stanley P. Rockwell graduated from Yale in 1907. First he worked as an electrical engineer, but a few years later circumstances brought him an active interest in the physical metallurgy of steel.

Stanley Pickett Rockwell was born in New Britain, Connecticut. He attended Yale University, was a member of the Yale crew, and graduated in 1907 from Sheffield Scientific School as an electrical engineer. Shortly after graduation, he got a job at the Lynn Works of General Electric Co., where he remained for about a year. He then entered the employ of the Stanley Works in New Britain, Conn., and it was there that he first became interested in the physical metallurgy of steel. In 1912 he joined the New Departure Mfg. Co., Bristol, Conn., taking on the duties of a testing engineer and metallurgist. It was at New Departure that Stan Rockwell really began to hit his stride as a metallurgist.

The New Departure Mfg. Co., at that time, was not only making ball bearings for automobiles, but whole automobiles as well. These were the pioneer days of the automotive industry, of alloy steel and its heat treatment, and the mass production of accurate parts. At New Departure, Rockwell found himself associated with a number of other young and enthusiastic engineers, one of them an ASM past president, Frederick G. Hughes. This group of young engineers literally ate and talked shop problems morning, noon and night — often far into the night. They had difficult problems to solve and they also had the courage, determination and resourcefulness to do it.

Shortly after coming to New Departure, Rockwell was given the job of supervising the hardening of ball races. The only method of checking the hardness of ball races at that time was by the use of a file. This method was far from satisfactory, being primarily a "go and no-go" test; Rockwell immediately realized that, if you were going to control hardness, you must have some kind of a yardstick for accurate measurement. He was dismayed at the lack of accurate tools for heat treatment, as compared with the equipment in the machine shop. The forthright Rockwell decided to build a hardness tester, and immediately began to study and experiment with various methods of measuring indentation hardness. He soon found that he had a real problem on his hands!

His first attempts were so discouraging that the average man would have dropped the idea. Obstacles, however, only acted as an incentive and those who watched him develop his hardness tester soon realized that perseverance was one of Stan's outstanding characteristics. It is difficult to estimate the amount of time he spent, or the great amount of work he did before he arrived at the basic principle of using both a minor and major load in measuring indentation hardness, and thus giving to the hardness test the high degree of accuracy he desired. He himself is quick to say that the aid and encouragement of his associates at New Departure were invaluable; they, on the other hand, would point out that no amount of aid and encouragement would have availed if Stan had not been made of the metal he is. One of the ten early machines was seen by Charles Wilson of the then Wilson-Maeulen Co., and this firm, in Rockwell's words "brought it to the attention of the public, sold it to those who needed it, and thus created business and employment".

During this pre-War period, carburized balls and races were rapidly giving way to balls and races made from alloy steel. This change presented many new problems to be solved. In order to get a better understanding of what happened when various alloy steels were heat treated, Rockwell began the development of a dilatometer for investigating the reasons for excessive distortion when these alloy steels were hardened. This first dilatometer was rather a crude affair, consisting of an Ames dial gage, a lever system and a quartz contact rod, assembled to a small electric tube furnace. From this crude instrument, Rockwell obtained valuable information as to what could happen when alloy steels were hardened. After the War he developed this dilatometer into an accurate working instrument, a task that undoubtedly required more time and study than the hardness tester; it has reached its present embodiment in a machine that automatically traces two curves, one showing changes of length with temperature during a heating and

cooling or quenching, and the other the corresponding changes of length with time.

In the fall of 1916, Rockwell became consulting metallurgist for E. F. Houghton & Co. This work offered him the further advantage of observing, at first hand, the steel problems of other manufacturers and how these problems could best be solved. However, the United States shortly thereafter entered the World War. He immediately offered his services to the Ordnance Department, which were accepted, and he was commissioned Captain.

After the War Rockwell became metallurgist and works manager of the Weeks-Hoffman Co., Syracuse, N. Y. However, being a good Connecticut Yankee, Stan Rockwell felt the urge to get back to his native state, and in 1920 he became metallurgist for the Whitney Mfg. Co. of Hartford.

For a number of years he had the idea that he would like to establish a consulting and engineering service, together with a commercial heat treating shop. He knew there was a demand for service of this kind and so, in 1923, he took this step and established the Stanley P. Rockwell Co. in Hartford, and is still actively associated with this company as vice-president and general manager.

There is no doubt that Rockwell's training as an engineer has assisted him in his work as a metallurgist. His approach to a problem is that of an engineer, he thinks along mechanical lines rather than physical-chemical lines, and he is always looking for a "practical" solution of the problem. He is a great believer in the "trial by error" method. Having been a man in the shop, Rockwell understands the shop-man's language; he understands their problems and is quick to get their viewpoint. He is a hard worker because he has an active mind. He is endowed with a keen sense of humor, especially when things are getting pretty tense, and when this moment arrives, he will often jump from the serious to the ridiculous by making some funny remark or telling a story and waiting for the storm to blow over. The following incident is a good example of his alertness under tense situations, which is quoted in Rockwell's own words.

"Some years ago I was called to Canada by the plaintiff in a sales infringement suit to give expert testimony in reference to differential automobile gears. The trial was held in what is equivalent to our State Superior Court, very formal, no jury. The trial lasted for about a week and I was on the stand a full day for cross-examination.

"During this cross-examination, one of the defendant's lawyers was continually trying to get me to answer 'Yes' or 'No' as to whether the steel used in the gears made by the plaintiff was better or poorer than other steels. This was a difficult question to answer, as several steels were recommended and could be used for that particular part, so the choice was based upon individual preference rather than any particular quality. Moreover, on direct examination I had made a statement that a great many factors such as forging, machining and hardening, as well as the final physical qualities, were all a part of a gear.

"This cross-examination continued in this same manner for several hours, exasperating His Lordship the Judge, the defendant's other lawyers and myself. The whole matter had come to an impasse and I turned to the Judge and asked if I could ask the defendant's lawyer a question which could be answered 'Yes' or 'No'. This request was granted and I asked 'What, in your opinion, is the best religion in Canada; is the Methodist better than the Episcopal?' He immediately threw up his hands and said, 'My Lord, he asks me a question on religion.' The ensuing laughter closed the court in short order. The final decision a month later was for the plaintiff."

Not being contented to forget the feel of his college athletics, Stan has also become a navigator, and he obtains most of his recreation and enjoyment aboard his boat The Chin Chin. Sometimes it will be a fishing trip on Long Island Sound or perhaps a cruise along the Maine Coast. Like most seafaring men, he also enjoys the thrills that go with it, even to the extent of riding out the hurricane of 1938 on the flooded Connecticut River.

Rockwell is a member of various engineering societies. He is still very actively engaged in many metallurgical problems and will undoubtedly make many more contributions to the art. In the words of Edgar C. Bain, past president ASM, "I am charged by the committee of past presidents to affirm that the basis of award of the Sauveur Achievement Award to Stanley P. Rockwell is in keeping with the spirit enunciated at the time of its creation. It is intended to recognize fundamental, basic contributions to the arts or technology of the metal industry, or subsequent scientific extensions and study by the originator, proven by time to have been significant and important." There can be no question but that Stanley Pickett Rockwell's development of hardness testing instruments and dilatometers falls into that category.

HORACE W. STAPLES

Welding Galvanized by a new method

By A. Ralph Eckberg,* ⊜

EASTMAN Kodak Co. has been a large industrial user of air conditioning for many years. Quality control of photographic film and paper has necessitated exact temperature and humidity conditions in nearly all of the important manufacturing departments. Hence, we have been building and installing large air ducts, air washers and other conditioning equipment of galvanized iron sheets for a long time. The conventional method of joining galvanized sheets, by riveting and then soldering for air tightness, does not provide a strong joint, and it is quite expensive in the construction of large sized equipment. Furthermore, the flux used for the solder often causes the formation of zinc oxide in moist atmospheres.

For these reasons we started, early in 1935, searching for an improved method for joining galvanized iron sheets, and finally developed a satisfactory method of carbon arc welding with a filler rod of copper-silicon alloy. These are commercially available under such trade names as "Everdur", "Duronze", "Herculoy", and "Olympic Bronze".

We found, however, that there was a margin along the seam from which the zinc coating was removed by volatilization during the heating of the weld and that this zone was in effect an unprotected area of bare iron which was extremely susceptible to rusting in air conditioning equipment or air ducts.

Further development of this process by T. S. Gaylord of our Metal Shop resulted in the proposal that the copper alloy rod should be coated with block tin. The tin melted very readily and spread out on the warm sheet, depositing itself adjacent to the weld metal. Under proper procedure the strip of what would have been bare iron was fully covered with molten tin at the same time the weld was deposited by the carbon arc.

Some idea of the protection given by this means may be had from the fact that it withstands two or three dips in the Preece test, a method much used in galvanizing shops to determine thickness and uniformity of coatings. [In this test, cleaned samples are dipped in neutral copper sulphate solution (36%) at 60° F. for 1 min., washed, and the copper deposit rubbed off. If the copper deposit adheres it is evidence that the zinc at that spot has been

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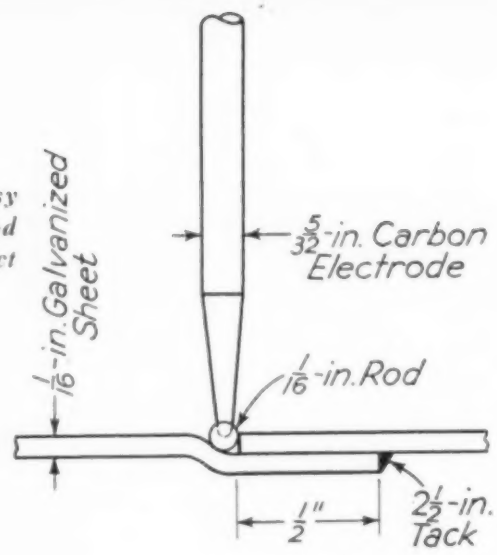


Jog-Lap Joint Provides Easy Control of Melted Weld Rod and Minimum Heat Effect

entirely removed. One such dip will remove ½ oz. of zinc per sq.ft. of sheet (both sides galvanized) under average conditions, and the above test might then be regarded as indicating a zinc coating of something over 1 oz. per sq.ft. (½ oz. on each side). Class A coatings in A.S.T.M. specifications call for 2¾ oz. per sq.ft. — EDITOR'S NOTE.]

The process outlined above, using a carbon arc with a copper alloy welding rod, tin coated, has now been effectively covered by letters patent. A more detailed explanation of the method and procedure of welding follows:

The carbon arc has a temperature of well over 6000° F. In the Gaylord welding procedure, the tip of the carbon is held approximately two thirds of the way through the copper alloy rod, which is laid flat in the groove or fillet of the seam. The melting point of the tin coating is 450° F., while its boiling or volatilization point at atmospheric pressure is about 4120° F. The melting point of zinc is 787° F., but its boiling point is very much lower, namely 1665° F. This, in fact, is lower than the melting range of the copper alloy rod—about 1865° F. As the heat of the carbon arc is applied, the tin quickly goes into a liquid form, the zinc on the nearby outer surface of the galvanized sheet melts and later volatilizes at 1665° F., 200° below the melting point of the welding rod. This then is the reason that the outer portions of the zinc coating are driven off adjacent to the welded seam. The tin, however, does not volatilize at all, but spreads out as a labile liquid, since the welding rod melts and alloys with the steel sheet at temperatures at least 2000° F. below the boiling point of the pure tin.

The carbon tip is moved along at the approximate rate of 1 in. for 5 sec., so that a new portion of the coated rod is brought into contact with the heat of the carbon arc. A microscopic examination of the protective coating which replaces the volatilized zinc adjacent to the weld discloses that it seems to be made of successive longitudinal layers of tin with finally an alloy of tin and zinc with the zinc content increasing with the distance away from the weld proper. The total width of this entire area, however, if the above procedure is correctly followed, will only be from 1/32 to ⅛ in. on each side of the weld on 16-g. galvanized steel sheets.

Experiments were made to determine the best type of joint for the Gaylord process. We tried several, from the plain butt joint to a straight lap joint, and finally settled on an offset lap joint as offering the best conditions. The offset lap joint or jog-lap joint presents the opportunity for laying the filler rod in a fillet as shown in the sketch at the top of the page. The joggle, or bottom portion of the lap joint, also helps to remove the heat of the welding

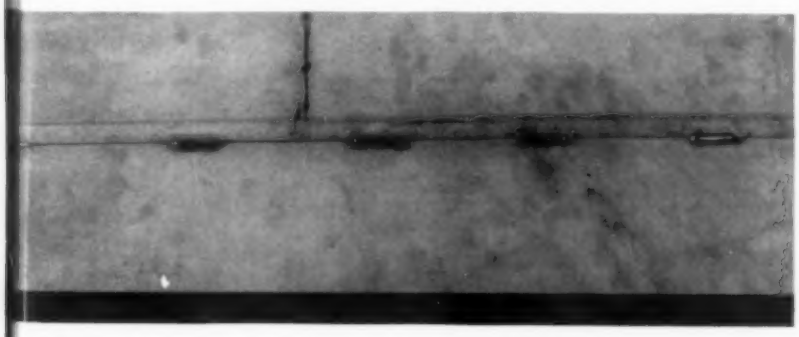
Gaylord Process Uses a Carbon Arc to Melt a Tin-Coated Copper-Silicon Wire Into Fillet of Jog-Lap Joint

current so that there is little or no damage to the galvanizing on the side of the sheet opposite the weld. (See the photograph below.) Numerous tensile tests have indicated that this type of joint develops approximately 90% of the strength of the galvanized sheet, with an average ultimate tensile strength of 51,000 psi. The recommended alloy welding rod analyzes approximately 2.5% Si, 1.5% Mn, with the balance copper.

It will be seen that this method of joining galvanized sheets has made possible important changes in the design of galvanized iron equipment. For example, the fact that we now have a joint with a strength of 51,000 psi. enables the designer of air conditioning equipment to figure on fewer hangers and consequently save in installation costs. This same strength enables us to build our air ducts and other air conditioning equipment of a size to allow for frequent cleaning by actually sending men through long runs of air ducts. The added cleanliness of such a practice, and the ability to inspect the conditions inside the ducts, have considerably improved the quality of our photographic products.

The experience of the Eastman Kodak Co. indicates, therefore, that in addition to providing a joint which is very much stronger, and one that is fully corrosion resistant to damp atmospheres, the use of the Gaylord process also results in lowered costs on the high grade type of air conditioning equipment and air ducts which we build and install in our various plants. We find that the final total labor cost is reduced by about one third, as compared to the cost of the conventional type of riveted and soldered joint. This is particularly true of long runs of air ducts, which normally require considerable expense in providing and installing hangers or other reinforcement.

Reverse Side of Jog-Lap Seam in Galvanized Sheets Showing Tack Welds at 8-In. Centers and Small Disturbance to Coating From Welding Heat on Other Side



Machining copper alloys

By W. B. Sallitt

Abstracted from The Metal Industry, *Sept. 8, 1939, p. 227*

COPPER alloys are now available in such wide variety that some logical method of grouping is indispensable. For the present purpose, a classification based on the type of chip has proven useful. Copper-base alloys produce three types of chip, according to whether their basic structure is homogeneous, duplex, or contains fine particles added to promote machinability. Machinability of these three groups will now be discussed.

Group A, homogeneous materials, includes copper, alpha aluminum bronzes, cupro-nickels, alpha nickel silvers, wrought phosphor bronzes and silicon bronzes, and beryllium bronzes in the softened condition. Owing to their high ductility, cutting operations cause a considerable amount of plastic deformation. For example, a turning tool with 20° top rake, operating on copper with a feed of 0.004 in., produces a shaving about 0.017 in. thick, indicating that the metal is being "upset" almost four times by the face of the tool. Since this cold work absorbs power and generates heat, it should be eliminated so far as possible by using steeply raked tools. The chips of Group A materials are very tough and strong; they are smooth on both sides and can rarely be broken by means of chip breakers; hence, disposal may sometimes be troublesome, coming off as they frequently do, in tightly rolled coils.

Copper and cupro-nickel are more "sticky" to machine than the cold working bronzes, since they tend to "freeze" or "build up" on the cutting edge, and to tear readily — particularly in operations such as screwing and tapping. Such difficulties are probably associated with the low rate of work hardening. To insure a clean finish relatively large clearances must be provided, the cutting edge of tools must be kept keen, and the cutting face should be burnished. To prevent chips from packing plenty of clearance space must be provided.

Top rake angles will be between the following limits (the angle generally increasing with ductility of the metal being cut): High speed lathe tools, 12 to 30°; forming tools, 10 to 15°; drills, 10 to 40°; taps, 10 to 15°; dies, 17 to 30°; milling cutters, 10 to *(Cont. on p. 676)*

Do Your Christmas Shopping Early!

Gifts of metal are most acceptable to the discriminating (Adv.) especially if of gold, platinum, silver or those other precious metals copper, aluminum and stainless. Above are items of aluminum, hand made by Wendell August Forge, Inc., Grove City, Pa.

Recirculating Air heating for industrial furnaces

This article was read before the 1939 meeting of the Industrial Section, American Gas Association, held in Cleveland. Convection heating has long been of prime importance in baking and tempering operations. Now Mr. Stephenson calls attention to large furnaces operating at temperatures up to 1250° F. (the limit of process and stress relieving anneal). Other manufacturers have raised this limit and built hundreds of successful furnaces for hardening, normalizing and all manner of high heat treatments.

By Edward Stephenson, Jr.*

FURNACES for heating objects up to 1250° F. have recently undergone a revolutionary change. Demands for rapid action and high uniformity have favored furnaces which use the convection principle — namely, the heating of atmospheric gases in one chamber and forcing these hot gases through the work in the furnace chamber. The engineer designs a heating machine that moves these gases around in a closed system, using some means to push or pull them, some means to heat them, and some means to control the absorption of heat by the products to be heated. Such a fundamental machine constitutes a "convection heating furnace".

When a furnace user and a furnace maker start to discuss the question "Why use a convection contraption when direct heating has been used for years?" they should realize that the points that insure a proper return on the purchaser's investment are the same as the items the builder must keep in mind when designing equipment to meet the specifications. Such requirements as fast heating rates at high thermal efficiency, and accurate distribution of heat throughout the charge, are met most easily and surely by the convection unit. Many heating devices are available, but some can never quite approach the good performance of others.

When this main question of performance has been decided, the next step is the consideration of details. These will now be discussed:

Furnace structure should be substantial for the anticipated life of the equipment. The trend is clearly toward steel plate and structural shapes, rather than castings. A good furnace should be founded on a steel bottom plate, and should be portable in the sense that it may be transported either whole or in sections from one part of the plant to another. Furnace structures may be bolted, riveted, internally or externally welded, dependent upon price limitations. The cheapest construction naturally has certain limitations as to application. Where extremely rigid structures are required, then welded construction is used throughout. Where neatness is desired, then internally welded structures are used. All the above methods of putting together a furnace structure are in use.

Linings for furnaces in the low temperature realm may be made of various substances, as

*Surface Combustion Corp., Detroit, Mich.

for example rock wool (a form of mineral slag), asbestos products, or combinations of the two, glass wool, aluminum or metal foil, calcined earths, or insulating firebrick. Each has its place, dependent upon temperature, expected life, and capital investment. The purveyors of linings have explored the economics so well that no attempt will be made here to justify any particular type of construction. Each specific problem has its specific answer. Of course, it is very necessary to know that the chosen lining will not shrink nor disintegrate at the temperatures involved, and will withstand handling, moving, or any one of a dozen other abuses.

Conveyors. The various types of conveying mechanisms used in high temperature continuous furnaces are all suitable, namely, woven wire belt, articulated link belt, apron conveyor, pen pusher, shoe pusher, roller hearth, walking beam, overhead chain or under chain type. Naturally, all mechanical devices for charging and discharging batch type or semi-batch type furnaces also apply. The fundamental point is that the ratio of the net weight to be heated plus conveyor to be heated to the net weight only shall be as close to unity as possible. This results in high fuel economy and smaller furnaces. I have in mind a particular installation in which 2300 lb. of work, 2600 lb. of pans, and 8000 lb. of chain were to be heated per hour; in this furnace the relation was opposite to what it should have been. (After redesigning this job the total gross weight was brought down to 4600 lb. from 12,900.) A careful examination of the furnaces proffered for a specific duty will result in the rejection of many types of conveyors, and the choice will depend on the investment possible and anticipated life of the equipment.

Heaters. In a fundamentally good heater the number of thermal units required to bring it to temperature is at a minimum. Careful consideration of the ideal heater should result in the principle that the *weight* of the heater should be at a minimum. Since most heaters are mounted on top the furnace, a saving in heater weight results in a saving in the furnace structure. If the heater is constructed so that incoming make-up and combustion air passes around the shell, and then back through the heater, a minimum of insulation will be required. Heaters should be preferably of the totally enclosed type — in other words, they should be lighted with a spark plug, and exclude any direct contact between the atmosphere within and without the heater. Naturally this means a completely closed burner and a piped system for combustion air and gas. Heaters

The Goliath of Convected Air Furnaces. It handles 70,000 lb. of oil well casing an hour and needs seven heaters to turn the trick

should be readily accessible and constructed so that the life is at least as long if not longer than the life of the furnace shell. Compactness is desired, to fit within relatively narrow confines. Heaters should also be efficient from the viewpoint of the heating medium. They usually should operate on the "blow-through" system in which air or gases are pushed through the heater and then down into the furnace chamber. The heater might, of course, be built within the furnace structure, but at present the trend apparently is to the external heater as being an easier solution of the problem.

Burner Equipment. From the heater described above as ideal, we must consider the following requirements:

1. That the burner equipment must be ignited by electric spark.

2. It should be completely piped in, so that no external flame is visible (unless surroundings, temperature, and other circumstances of the particular job permit the use of open flame burners).

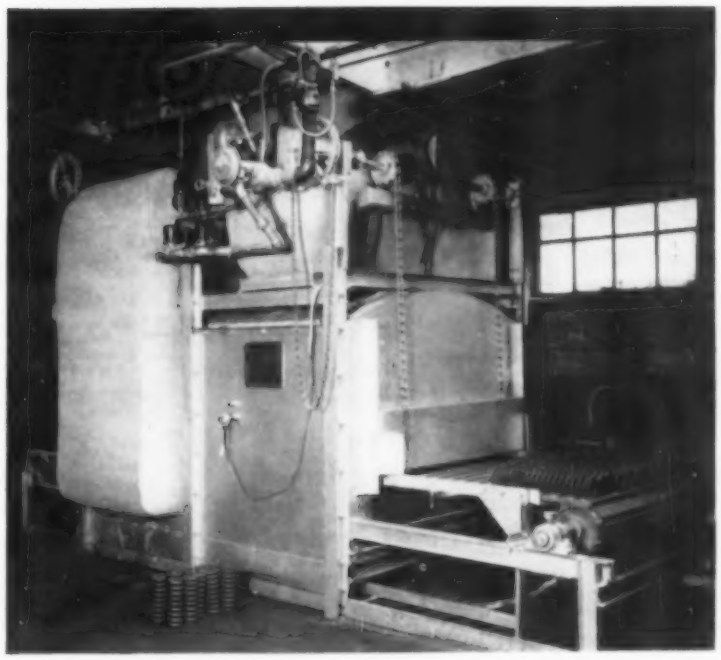
3. It should be of such a design that *one* valve, either air or gas, controls the quantity of fuel admitted, always in correct ratio, gas-to-air. Also the ratio or carburetion of the air-gas mixture should be uniform over the ranges of volume desired, to permit maximum combustion efficiency.

4. The inspirator and the burners should be of such design that inspection and minor repairs may be easy and simple; also that a change in fuel will occasion a minimum of changes in the carburetor and burners.

5. The equipment should be of such materials as to insure a life equal to the other furnace details.

After the designer has considered these points, he must also correlate his firing systems with his heaters. From the above we can see the vital importance of a correctly tailored firing system to the furnace.

Fans. There are two types of prime movers to force the air around, the radial and the disk types of fans. The radial or paddle wheel type of fan apparently is the most successful, and is widely used. It will move gases at any of the velocities required in convection heating and against any of the back pressures encountered in normal furnace loads. It can have water-cooled bearings applied and can be constructed



This Pigmy — by Comparison With the Casing Annealer Shown on the Opposite Page — Draws the Temper of Coil Springs With Speed and Precision

of simple alloys. In short, it is an efficient medium for moving air by push-through operations against considerable resistance.

The other type of fan is the disk or impeller fan. It consists of a disk with blades set at an angle, and is primarily a displacement fan. The parts move at non-uniform linear velocities across the diameter and unless careful provisions are made, "back lash" occurs, and the air being displaced on the periphery is pulled back into the center of the fan. Very little is known of its actions at rarefied densities and high temperatures. At normal temperatures its efficiency drops off when the optimum velocity and resistance pressures are exceeded.

Temperature Control. The temperature control equipment can be of any of the commercial types available (such as outlined by L. G. Bean in his article on page 404 of last month's METAL PROGRESS) although it preferably should be of the throttling type. The reason for this is that a convection heating furnace of proper design will change the volume within the furnace chamber many times a minute, and therefore the system itself is highly responsive to slight changes in temperature. Off-and-on control would probably result in serious hunting, while a throttling type of control would minimize the swings in temperature to one side or the other of the control point.

Safety. Safety devices should do everything

that a man of more than average intelligence would do! They should be prepared to shut down the unit should any of the following things go wrong: Power failure, slippage of the belt on circulating fan, failure of combustion air, failure of the gas being fed to the system, failure of the pilot to remain lighted, or failure of the flame within the heater to remain lighted. Because we ask for a completely enclosed system, obviously it must of itself provide for electric ignition. It should also provide that necessary and important time delay after the fan begins to move, and before ignition is turned on.

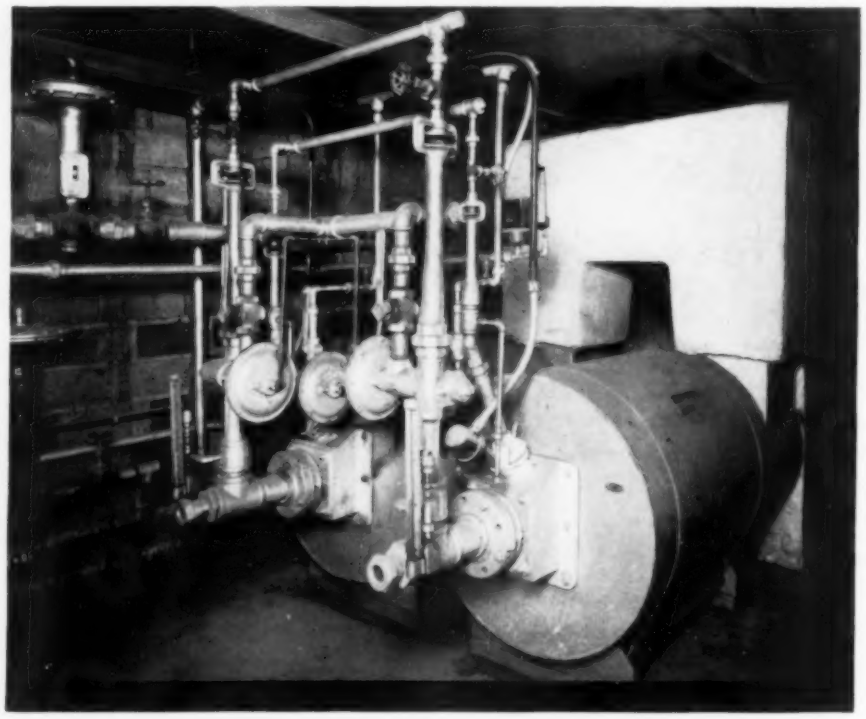
Safety control equipment is called upon to function in those rare moments when something goes wrong which should not have gone wrong. A piece of equipment might be lighted every day for five days a week for 51 weeks, and on the third day of the 52nd week, the safety control equipment may be called upon to function, and must act not only as a unit but within a prescribed time limit. Such safety equipment does not have to be sensitive to fluctuations — for instance, on the pilot gases or in the combustion air — but should any of these completely fail, it must then act promptly and without any possibility of failure.

Let us say that a unit is running, and the electrical parts include a combustion air blower drawing 440-volt, 3-phase, 60-cycle current, a temperature control circuit on a 110-volt, 60-cycle circuit, a safety circuit of 110 volts and 60 cycles, and furnace conveyors driven from 440-volt, 3-phase, 60-cycle lines. Gases are fed to the system under 2 oz. pressure. Suddenly the power circuit on the 110-volt safety circuit fails after the unit has operated successfully for some time. Immediately all gas valves on the pilot and main burner must close, for they are operated from the same source. Since the combustion air blower is still being driven from the 3-phase lines, any gases trapped between the cut-off valves and main burners will be purged. At the end of probably 7 to 8 sec., the complete unit should be off the line.

Such a shutdown should be equally certain if the connecting belt between the circulating fan blower and its motor failed, or if the texrope drive pulleys slipped, or if a pin broke, or if any one of a number of vitally disturbing things happened which could occur on such a system. These things occur at unpredictable times. Therefore, the safety circuit, of itself, must have the constitution of an alligator and the brains of a superman. It is consequently recommended that safety circuits be carefully examined to determine whether they meet every predictable condition that will be imposed upon them. Maybe low-priced equipment will be suitable, but dollars cannot be spared if expensive devices alone will function reliably.

Duct Systems. The design engineer has available several methods to apply heated air to the work to be heated, regardless of whether the furnace be of the continuous conveyor or batch type. He can put all the heat in at the top and pull it all back at the bottom, or he can put it all in at the bottom and take it out on top, or he can split it, putting part in at the bottom and part at the top, and take out either at the top or bottom or both as desired. It would

A Double-Barreled Heater For Baking Lacquered Finish on Automobile Bodies. The baking oven is overhead, and the view is shown primarily to indicate the elaborate temperature control and safety devices



appear obvious that if you apply heat simultaneously to top and bottom of the charge, the heating time will be reduced. This is a fundamental of high temperature furnaces, recognized for years, and it follows that hot incoming air should be split, unless ruling considerations dictate otherwise.

The theory of flow of heated gases across surfaces resolves itself into several forms, and to these names have been given such as streamlined flow, lamellar flow, viscous flow, and turbulent flow. In the majority of cases these can fortunately be identified by the velocity or movement of gases. The fundamental principle of convection heating furnaces is to put a film of hot gases around the work and wipe that film off as soon as the heat is abstracted from it. The greater the rapidity with which this takes place the greater is the heat transmission. Therefore, due consideration should be given to the flow in relation to the objects to be heated, and the penetration of gases down into extremely thick loadings. The latter is of more importance, perhaps, in a batch type than in a continuous furnace.

We must remember that the fundamental principle of natural convection is that heated air rises and cold air falls. Therefore, if it is desired to bring the temperature of the furnace to as great a uniformity as possible, the return ducts should be from the bottom of the furnace. Whether they be located in the ends, the corners or elsewhere is a matter which is governed by conditions. Time has proven, however, that exits from the ends of the furnace usually are of simplest application to the furnace and give maximum heat efficiency. Many furnaces must not only heat the work, but maintain it at temperature for a considerable time. This introduces the problem of multiple zones and multiple heat application. That this is possible in a wide variety of specific cases is proven by one furnace, with seven zones of control, heat treating approximately 70,000 lb. of oil well casing per hr., and another with two zones of control which handles approximately 45 lb. of small parts per hr.

Conclusions. From the foregoing it can be seen that the fundamentals of the application have been well tested in numerous instances. The problem of selecting a furnace of this type is no longer something which is dark and mysterious, but rather can be approached by both salesman and prospective purchaser with an open mind and an engineering eye.

Physical plus chemical specifications for bearings

By Robert G. N. Evans

Consulting Engineer, Milwaukee, Wis.

FOR SOME 28 years the author has been concerned with the problem of friction. Sometimes this problem has been friction between like materials, such as steel on steel or cast iron on cast iron; sometimes between unlike materials, such as aluminum alloys on steel or cast iron, cast iron or steel on babbitt, cast iron or steel on the various bronzes and other trade named alloys. The behavior of the mating parts (under the stresses imposed by the action demanded) gave considerable concern, even when all variables were controlled other than the structure of the two metals.

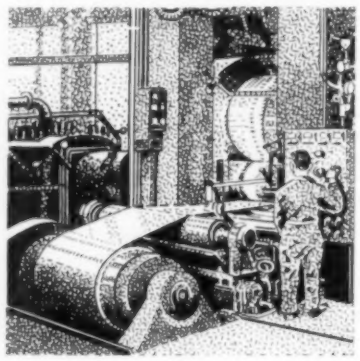
For instance, we might be working with cast iron cylinders and cast iron or light alloy pistons taken from regular production. We might be attempting to duplicate previous test results with what was given to us as the same materials as previously used. Or we might be working on a new combination, such as a carburized steel piston pin against bronze, or a hardened steel shaft against babbitt. In any event, we would achieve satisfactory results in the test work, using materials obtained from various sources, each item shipped presumably on one order (and, we suppose, manufactured in one run in each supplier's plant) and the supplier either using his own favorite practice or meeting specifications which we had set up for the chemical composition.

We would always find certain limits which could be manufactured with economy under which these test materials had given desired results. The purchasing department would be given a blueprint with only the dimensions and chemical specifications noted; the material would then be purchased from what was thought to be reliable sources, many times on a price basis. Materials were then assembled in accordance with the limits indicated in the test work. In other words, we would hold all the manufacturing variables within the bounds determined by the test procedure, yet we would immediately experience difficulty with seizures which could only be interpreted as erratic behavior of the materials under operating rather than test conditions. Clearances would

then be opened up (after assuring ourselves that surface differences and alignment were comparable with those used in the testing procedure). Reasonable satisfaction would then ensue, with the exception of isolated seizures, and a general increase in noise.

We have been prone to accept this condition as "just one of those things" to be endured until manufacturers of all the component parts became research-minded.

A decade spent directing the research for a progressive manufacturer of bronze bearings led into a detailed investigation of the structures of bearing materials as they are affected by fabricating procedure. This investigation told us why we had been getting seizures in operation after the preliminary test work had proven the metals, surface finish and running clearances and then these metal specifications and tolerances were given to the manufacturing department. It concerned manufacturing variables in the structure of the metals or alloys involved.



Steel companies, years ago, realized that the chemical specifications were only one item in the making of a uniform product; hence their free use of physical and microscopic tests (even though they do not like to see them in actual steel specifications). It is well known to maker and consumer alike that the chemical specifications alone do not produce maximum physical characteristics, and the control of this manufacturing technique in all phases is responsible for today's uniformity of high grade carbon and alloy steel.

As previously stated, the erratic behavior of the metals in a bearing under working temperatures and stresses is due to lack of uniformity in the structure and physical characteristics of the metal parts involved. This brings us right down to where we are today: We are still experiencing erratic behavior in bearing metals, due, I believe, almost entirely to the general lack of understanding among the users of bearings that *chemical* specifications alone do not produce maximum physical characteristics and that it is the physical characteristics, on the other hand, which qualify a material for use in a given application.

It is quite obvious that if a metal is proven by testing procedure and this original material has had rigid manufacturing control, hence maximum physical characteristics, and then subsequent materials are purchased on a chemical basis alone and do not have the same physical qualities as the metal tested, we may expect any number of different metal structures and erratic behavior of the metal. No blame for lack of physical characteristics or proper structure of parts received can be placed at the door of the purchasing agent as long as he has only chemical specifications to guide him in the purchase.

I would not say that manufacturers of bearing metals do not insist on correct foundry procedure for maximum physicals because it raises the price of their product and they believe it is immaterial, but I do say that any manufacturer who does not have a manufacturing technique which *controls* major variables and thus assures the customer of sound, *uniform* metal or alloy (which procedure also saves him foundry scrap) has no reason to expect to be favored by customer orders. There is no excuse for bad materials getting into the user's hands. Ignorance on the part of the user certainly does not warrant the shipment of inferior materials.

Non-ferrous metals, like steel, have definite duties to perform; therefore, they must possess optimum physical characteristics. Steel manufacturers and users found that it took a definite procedure in manufacturing to produce steels without deficiencies and with uniform structures. Non-ferrous fabricators and users must realize this same thing is true with the non-ferrous metals. Those metal manufacturers who are conscientious builders and have the protection of their customers in mind should receive a measure of protection against the less skillful, less well equipped or less conscientious producer. Likewise, the engineer or the user must be protected against the delivery of unsuitable materials.

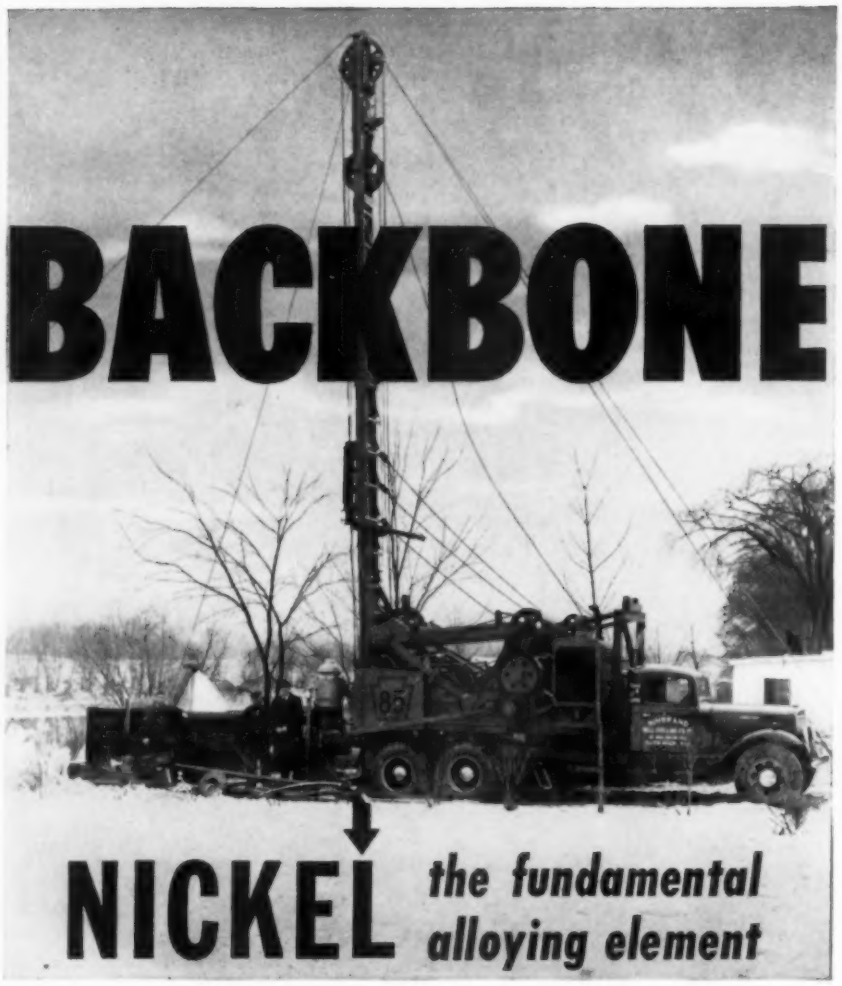
The best protection for both is the setting up, on the blueprints, of the physical characteristics required in the metal. At least, then, the thought will enter the seller's mind that if the company requesting the quotation has placed physical characteristics on the blueprints, it knows the value of them and has a method of checking incoming material.

Specific Effects of Alloys in Steel

Element	Solubility		Influence Exerted Through Carbides			Influence on Ferrite	Principal Functions
	In Gamma Iron	In Alpha Iron	Carbide Forming Tendency	Effect on Hardenability	Action During Tempering		
Aluminum Al	1.1% (Increased by C)	30% ±	Less than Fe (Graphitizes)	Mildly positive (If any dissolved in austenite)	.....	Hardens considerably by solid solution	1. Deoxidizes efficiently 2. Restricts grain growth (by forming dispersed oxides or nitrides) 3. Alloying element in nitriding steel
Chromium Cr	12.8% (20% with 0.5% C)	Unlimited	Greater than Mn Less than W	Moderate (Up to 1% more effective than Mn)	Mildly resists softening	Hardens slightly (increases corrosion resistance)	1. Increases corrosion and oxidation resistance 2. Increases hardenability 3. Contributes some strength at high temperatures 4. Resists abrasion and wear (with high carbon)
Cobalt Co	Unlimited	80% ±	Similar to Fe	Negative (That is, decreases it)	Sustains hardness by solid solution	Hardens by solid solution	1. Contributes to red hardness by hardening ferrite
Manganese Mn	Unlimited	15 to 18%	Greater than Fe Less than Cr	Moderate (Ni < Mn < Cr) Retains austenite	Very little, in usual percentages	Hardens markedly and reduces plasticity	1. Counteracts embrittlement by inevitable sulphur 2. Increases hardenability inexpensively 3. Forms batter resistant steel (high Mn, high C)
Molybdenum Mo	3% ± (8% with 0.30% C)	32% (Less with lower temperatures)	Strong Greater than Cr	Great (When dissolved) Mo > Cr	Opposes softening by a secondary hardening	Gives age hardening systems in high Mo-Fe alloys	1. Raises coarsening temperature of austenite 2. Deepens hardening 3. Raises hot strength, creep resistance and red hardness 4. Enhances corrosion resistance in stainless
Nickel Ni	Unlimited	25% ± (Irrespective of carbon content)	Less than Fe (Graphitizes)	Mild Retains austenite in medium carbon steels	Very little in small percentages	Strengthens and toughens by solid solution	1. Strengthens unquenched or annealed steels 2. Toughens pearlitic-ferritic steels (especially at low temperature) 3. Renders high chromium-iron alloys austenitic
Phosphorus P	0.5%	2.5% (Irrespective of carbon content)	Nil	.....	.....	Effective hardener by solid solution effect	1. Strengthens low carbon steel 2. Increases resistance to corrosion 3. Improves machinability in free-cutting steels
Silicon Si	2% ± (9% with 0.35% C)	18.5% (Even with considerable carbon)	Negative (Graphitizes)	Moderate	Sustains hardness by solid solution	Hardens with loss in plasticity Mn < Si < P	1. Used as general purpose deoxidizer 2. Alloy for electrical and magnetic sheet 3. Improves oxidation resistance 4. Increases hardenability of steels carrying non-graphitizing elements 5. Strengthens low alloy steels
Titanium Ti	0.75% (1% with 0.20% C)	6% ± (Less with lower temperatures)	Maximum (2% Ti renders 0.50% carbon steel unhardenable)	Strong, if dissolved (Persistent carbides restrain grain growth and withhold carbon; therefore reduce hardenability)	Persistent carbides probably unaffected	Age hardening systems in high Ti-Fe alloys	1. Fixes carbon in inert particles (a) Reduces martensitic hardness and hardenability in medium chromium steels (b) Prevents formation of austenite in high chromium steels (c) Prevents localized depletion of chromium in stainless steels during long heating
Tungsten W	6% ± (11% with 0.25% C)	32% (Less with lower temperatures)	Strong	Considerable, especially in small percentages	Opposes softening by secondary hardening	Age hardening systems in high W-Fe alloys	1. Forms hard, abrasion resistant particles in toolsteels 2. Promotes red hardness and hot strength
Vanadium V	1 to 2% (4% with 0.20% C)	Unlimited	Very strong V < Ti or Cb	Marked (When dissolved)	Maximum for secondary hardening	Hardens moderately by solid solution	1. Elevates coarsening temperature of austenite (promotes fine grain) 2. Increases hardenability (when dissolved) 3. Resists tempering 4. Gives marked secondary hardening

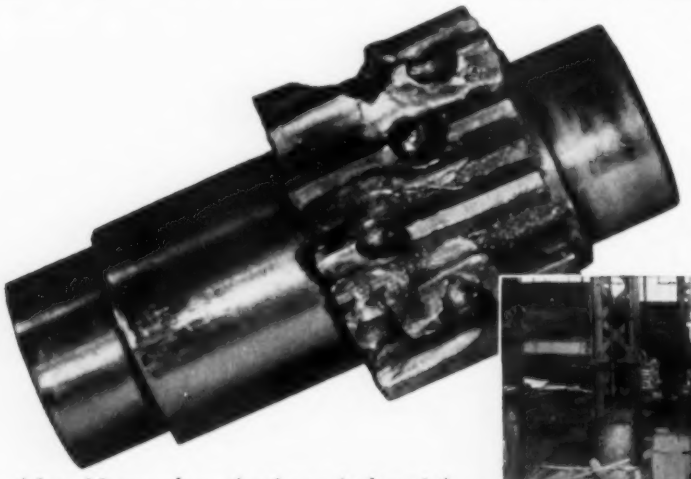
Adapted from "The Functions of the Alloying Elements in Steel" by Edgar C. Bain; published by

Gives steel
MORE BACKBONE



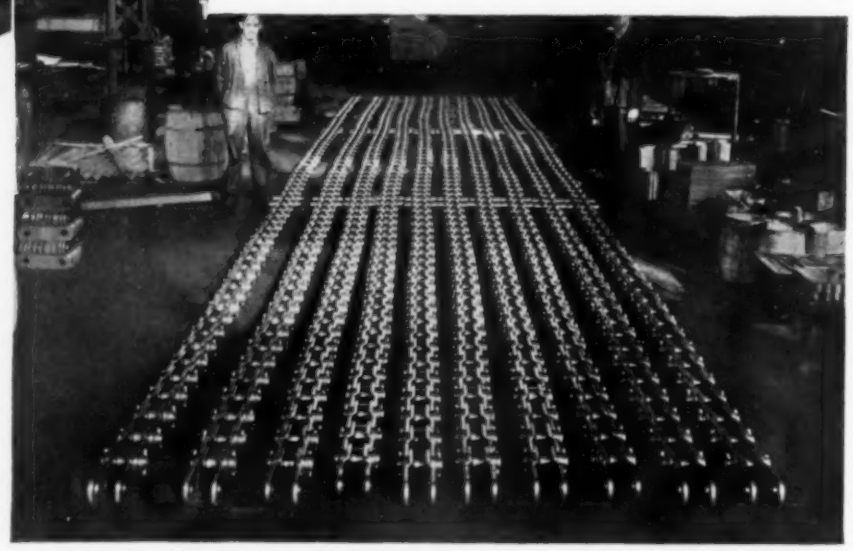
Rapid, repeated raising and dropping a 3,000 ft. string of drilling tools puts terrific shock stress and fatigue strains on portable drill rigs. This Keystone spudder uses Nickel alloy steels for transmission shafts and other vital parts. Nickel alloy steel shafts in this equipment have failure-free records of more than three years' service. Plain carbon steels, previously used for shafts, often failed in three to four months. Adding Nickel — the fundamental alloying element—to irons and steels guards against costly breakdowns on your equipment.

NICKEL *the fundamental alloying element*



Nickel alloyed into steels and irons imparts added strength, toughness and wear resistance. Evidence is these tainter gate chains produced from Nickel alloy steel by the Goodman Mfg. Co., Chicago. 1⅞" pins showed a breaking load of 539,000 lbs. and a yield point of 431,000 lbs. These chains dare not fail for they control flood gates on Mississippi River dams. For vital units in your plant, specify Nickel alloy steels. Your consultation regarding uses of Nickel alloys is invited.

After 12 years' service in an industrial truck this Nickel alloyed gear still retained toughness and ductility. The photograph shows how it battered but did not break when balls from a shaft bearing fell between teeth of gear and pinion. The gear is heat treated SAE 3135 Nickel-chromium steel, the same alloy specified today. Nickel alloy steels have backbone to stand up under long severe service. No wonder they prove so economical on a per-year basis.



THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

A metallurgical Secretary

visits the metal show

By Barbara O'Malley
Lindberg Engineering Co., Chicago

WHEN THE BOSS dropped a packet of invitations on my desk with the order "Send these to this list of customers — and there is also one for each of the girls" we were delighted. We had heard that the Metal Society's shows had been getting better and better looking, and we like decorative effects — especially when adorning something rugged and substantial. There also was a serious side. At this crucial moment in the World's political affairs, with the European nations warring and their misery-likes-company attitude, even we women are realizing that victory in war is becoming less and less a matter of man power, and more and more a matter of machine power. The ability to produce, in quantities with quality, the guns, shells, airplanes, trucks and tanks of modern fighting machines is likely to turn the scales to victory. And so here I am, in the greatest of all metal shows, anxiously looking for assurance that American industry is so far out in the lead that no nation will dare think of testing its power, that our brothers and boy friends will continue to ride in roadsters rather than tanks.

The first impression of the Show verified the rumors we had heard about it. Along with an unquenchable scientific thirst, these men also possess a definite sense of beauty. A far cry from the thought of misery and war is this beautiful bank of growing flowers and evergreens that entice one into the exhibit of U. S. Steel Corp. or of Allegheny Ludlum. Even the grass growing around the borders is real sod, and the lovely stone benches in each corner are covered with lush white leather cushions. The fountain in the center of U. S. Steel's area splashes peacefully, and I try to connect this beauty and thoughtfulness with a so-called soulless corporation. In the center of this garden is a brilliant pagoda showing amazing miniatures of old steel methods; of the first blast furnace between the hills of Homestead, with an illuminated colored picture in the sky of a battery of modern blast furnaces; in another panel is an old rolling mill driven by a water wheel and behind this the immense four-high rolls that turn out miles of plate for automobiles — or tanks. And beyond this is peace again, a pathway into a second garden.

But enough of the gardens for here is the carnival. Extending almost the whole length of one side of the amphitheatre is our own Lindberg booth (Adv.) garishly done in reds and golds, with calliope, clowns, magicians, and a puppet show. Hero of the puppet cast is A. N.

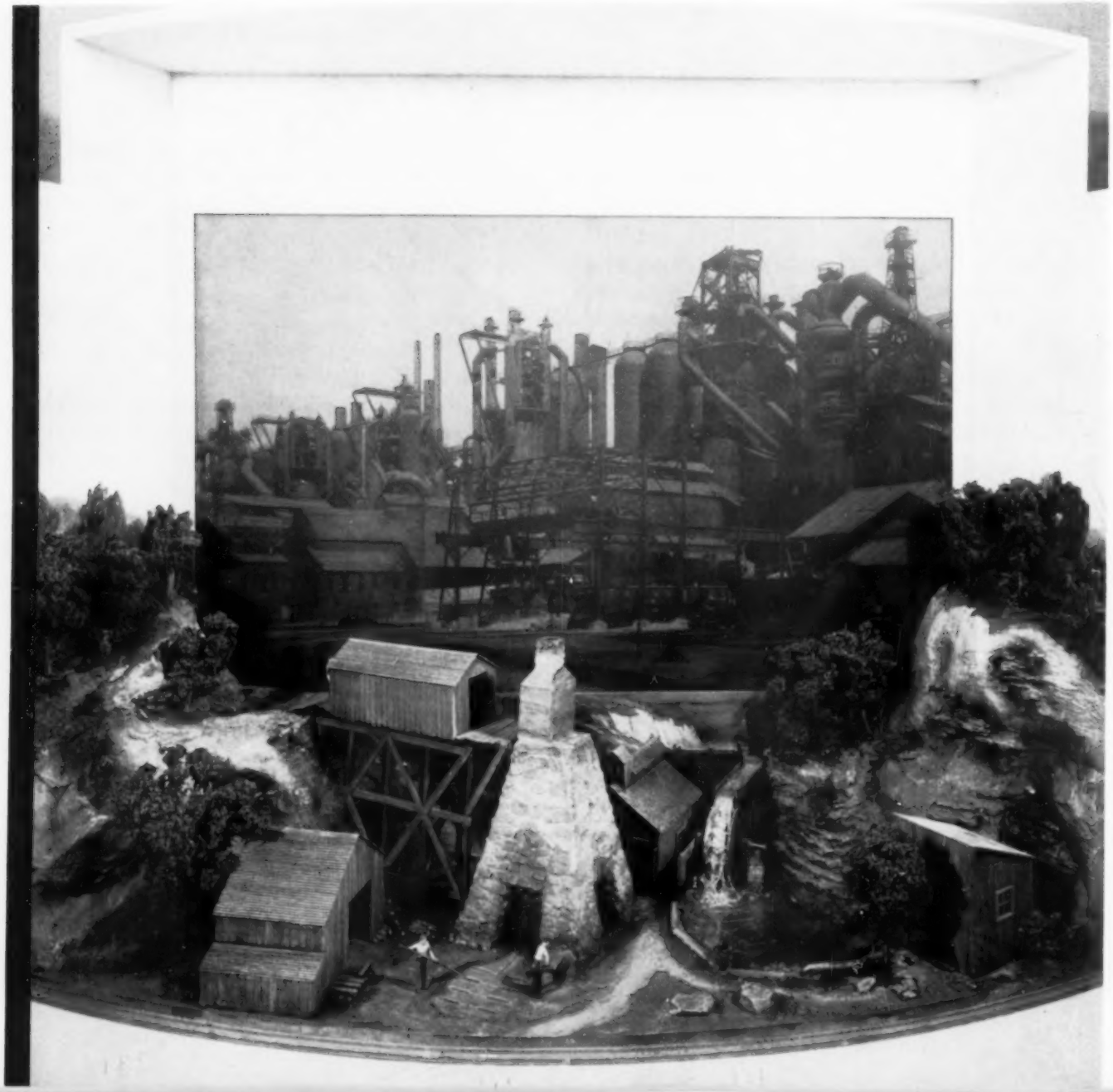
Lindberg, an old timer in the steel business in Chicago, with a cast of marionettes whose antics keep the crowd in constant laughter. On a stage is a magician who pulls rabbits out of the furnaces and heat treats steel in a hat, but even more amazing are the changes inside a piece of steel these metallurgists bring about without giving it a blush of color on the very outside, all in a furnace at bright red heat. This seems to be of great interest to the crowd, but as far as I could see the steel parts coming out didn't look any different from the way they went in.

The next booth by Pangborn looks like a section of a battleship, but turns out to be a method of cleaning steel with sand. You see, I have still the belligerent idea, and this is hardly dispelled by the A.S.M.'s own exhibit, which has a suit of Crusader's armor, and on another dummy is body armor, tailored in 1939 to repel rifle fire. I think the Audubon Wire Cloth Corp.'s booth would have been the popular spot with a knight of old, where he could drop in for a plain weave business surtout.

At the Ohio Crankshaft Co. he would have wondered at the crankshaft for a fighting ship, a big forging reaching to the ceiling. It must have been treated in a Tocco Senior machine, for the Tocco Juniors on display were for little stuff. They were dressed up in as neat a case as many a radio cabinet, and they are like radio in other ways as well, for there is no furnace to heat the metal, just invisible "high frequency electric currents". The patient man in charge also said he could change to fixtures for another job in four minutes, for the connections require only two electrical wires and two water hoses.

Beyond is the gas furnace section—a forest of silver furnaces, flames shooting in all

Old Hillside Blast Furnace; Furnaces Like This Were Scattered All Over Pennsylvania, Close to Ore Deposits. Charcoal made locally furnished the fuel and the air blast was powered by a water wheel. Behind the model is a transparency showing a battery of modern blast furnaces. (One of the dioramas exhibited by U.S. Steel Corp. subsidiaries at the National Metal Exposition)



directions, as enchanting as Fourth of July. I am told that the gas people always pool their exhibits in one big area, a good idea I should think, as it provides even the little fellow with well-planned and interesting surroundings all in keeping with the idea he wishes to promote. I find being a woman is a great advantage because no one tries to sell me a furnace but everyone seems glad to answer my questions, which are probably pretty foolish.

In the adjacent halls are working exhibits showing melting, cutting, welding and forming of steel, copper, brass and aluminum. White hot torches in gangs automatically cut plates like butter, guided by wooden patterns. If many are needed, these flame cutters go just as easily through a stack of plates as one. If only one or two are required, they simply draw a picture of the part on paper and trace a little wheel over the lines, and the torch cuts out an exact duplicate from steel plate six feet away. A handsome chap told me that they could also take thin slices from all over the surface, or fancy cuts just like a machine shop.

In Metals Disintegrating booth is a new way of making metal parts which detours melting, rolling, machining and grinding. They simply put the powdered ingredients together like making a batch of biscuits and press the mixtures under tons and tons (also like my biscuits on Blue Monday). If the part requires lubricants, they throw in a few holes to hold the oil. At first it seemed silly to grind up metal just to squeeze it back together again, but it must work, for I overheard one man say his firm bought powdered copper by the carload.

And I must tell Sis that she can have the baby's shoes coated with metal from a spray gun. Those on display looked precious, and the gentleman assured me they would wear for years and years!

The American Brass Co. have worked in an original idea, but maybe I should say "taken their own medicine". It is easy to take! The booth is equipped with furniture made of their own product, copper, and the seats are covered with blue leather, giving them plenty of feminine appeal, which reminds me that my feet are beginning to feel like a day at the World's Fair.

However, appealing as the dainty copper chairs are, too many people make it an inconvenient resting spot, so I hie me to the little theater of the Aluminum Co. of America. Here is a talkie that teaches me the history of aluminum, and I see how it is mined, smelted and fabricated. It seems so very, very complicated I wonder how we can ever buy an aluminum cup in a 5 and 10.

After 15 min. I gather my notebook, bag and coat and push back out into the crowds. At the Driver-Harris booth I am shown nickel-chromium alloys which last indefinitely at bright red heat. I am told that an American named Marsh, about ten years before I was born, developed these alloys for heating elements and furnace parts. My mother heated her curling iron over a gas jet, I remember, and so must have everyone until Mr. Marsh's alloys were used for curlers, toasters, pressing irons and so many modern conveniences.

(Speaking of household helps, any woman would be fascinated with the degreasing machines at the Blakeslee booth. Another boon for pots and pans!)

In the Dow Chemical Co.'s exhibit are many parts made of magnesium, one third lighter than aluminum. They told me that the Germans make more than half the World's magnesium, for it is the one metal whose ore is very plentiful in their own country. Ores for all the other metals, like iron and copper and zinc and lead and aluminum, have to be imported in great quantities because Hitler does not own enough mines. I suppose we would like to sell these ores and metals to the Germans if they would only be nice about it.

Further along are instruments that measure the temperature of steel to a fraction of a degree, instruments which are standard for the World, and others that show how much bigger a metal gets as it heats. (Metals do the strangest things!) Then there are X-ray machines that look into the walls of a steel casting to search out the defects. Machines that pull metal apart to find out how strong it is and how much it stretches before it lets go. Testing equipment that reads the hardness of steel, its strength and its resistance to vibration. Also metals get tired I suppose, just like this Metallurgical Secretary at the Metal Show, for I saw some fatigue testing machines.

There are so many wonders in the metal industry that I know I have not reported half of those I would have seen had I been an engineer on the lookout for new materials and ideas. He should come and see for himself; 33,000 of them did — half of them on the afternoon I was there, I think! At any rate, I can report back to the Women of America, "Your men are ready."

Critical Points

by the Editor

SPENT many extra hours in revising a 65,000-word article on "Iron and Steel" written in 1927 for Encyclopedia Britannica, a new edition of that work now being under way. A list of the important additions or corrections may be a gage of progress in the last dozen years—either of the industry or of the EDITOR. For what it is worth, here it is: Beneficiation of Lake Superior ores; desulphurization of pig iron with sodium carbonate; revival of bessemer steel for engineering purposes (fast machining); various items of openhearth practice as *(a)* slag control, *(b)* grain size control, *(c)* American scrap and hot pig practice, *(d)* British continuous practice with little scrap; high frequency melting furnaces; rimming steel; continuous wide sheet mills and the great expansion in sheet uses. The section on alloy steels was entirely rewritten to systematize the subject, point out the trend to low alloys, controlled grain size and hardenability, and the rise of molybdenum. Extensive additions were also made on the heat and corrosion resisting steels, cobalt and molybdenum high speed steels, controlled atmospheres in heat treatment, localized heating with high frequency induced currents (Tocco process), on the nature of martensite and transitional microstructures, and the intermediate structures in quenched alloy steels.

12-year progress in steel

To East Pittsburgh to inspect a new tool hardening furnace devised by JOHN GIER and HOWARD SCOTT of the Westinghouse organization. They had been impressed by the advantages of dissociated ammonia as a protective atmosphere, believing that its inertness to engineering steels, stainless steels and toolsteels was worth its relatively high cost (1¢ for 3 cu.ft.). It has to be dry and kept dry, however, else the gas become an active decarburizer. Here was the difficulty, for it seemed impossible to lock all air out of a muffle by doors on any tool room furnace. GIER's most ingenious solution of this problem consists of a bottle-tight muffle without doors—that is, entirely closed at one end, and set on a slope with closed end up. To the open end is welded a water-jacketed prolong of the same internal dimensions (no separating door) and at the end of this is an ordinary door, around whose edges burns the slow outflow of gas piped into the topmost hot end. When this door is opened, air enters only the lower corner. The entering charge rests in the lower cold zone a few minutes until this contamination is purged; it is then shoved up, by a bar, into the hot end. Excessive radiation from this region is prevented by a cellular end construction of the tray, made of thin pieces of nickel sheet and of dimensions to clear easily the inside of the muffle. After proper heating the tray is let down into the water cooled prolong, and is still surrounded by dissociated ammonia during cooling. Such a hardening process is, of course, restricted to air-quenching steels, but it so happens that many highly desirable and inexpensive punch and die steels fall into this class. SCOTT insists that the claimed advantages of die steels that require oil quenching are more than offset by their inevitable warping and danger of cracking during quenching.

controlling a controlled atmosphere

Spent a pleasant afternoon with ALLAN BATES, head of the Metallurgical and Chemical Division of Westinghouse Research Laboratories, and saw many interesting things, both old and new. The newest was refrigerator doors made of molded plastics rather than enameled steel. A little less new is a spick-and-span department devoted to spectroscopy and micro-chemistry (in charge of BRUCE ASHCRAFT). Here is a balance having ten times the sensitivity of the ones assayers use to weigh gold buttons. Perhaps you have had your name, written on tissue paper with hard pencil, weighed on one of them. Divide this infinitesimal by

accurate to infinitesimals

ten, and then realize that the modern micro-balances can accurately weigh vastly larger masses; the result is the ability to weigh a millionth of a gram in a gas absorber weighing 50 grams.

A 15-year old project in the same laboratory is P. G. McVetty's study of the creep of hot steel under steady load. He has built quite unconventional equipment; three large furnaces each enclose a 1-ton cylinder of 5% chromium steel, 4 ft. high, through which are bored 12 holes near the surface for enclosing as many specimens, 27 in. long. Elaborate precautions are taken to load and heat this metallic mass uniformly and steadily, and to measure the changes in length of each specimen, again with accuracy vying that of the micro-balance. Four types of steel, utilized in high pressure steam turbines, are under study — the carbon-molybdenum cast steels for casings, the nickel and chrome-moly steels for rotor shafts, the stainless steels for blades, and the low alloy steels for bolts. The latter have reached the unbelievable size of 6 in. diameter by 5½ ft. long; they are expanded by the heat of electric currents before assembly, so their initial setting-up tension is due to thermal shrinkage. Relaxation under steady stress must be slow; it is related to creep under steady load, but so intricately that no mathematical formula has yet been devised. No Westinghouse turbines have ever failed from creeping steels — a matter of professional pride to McVetty and his associates, but it would appear to an outside observer to be a matter of difficulty when continuing research expenditures are to be justified to a directorate, economy bent.

creep tests insure safety

[Speculative Addendum — Some steels, after certain heat treatments, *shrink* a little during long stay at temperature — say 1000° F. In our metallurgical Utopia we will have alloys whose microstructural changes causing shrinkage will occur at a rate that will balance the plastic extension due to external load. Or else — steels which work harden at a whisper, to resist automatically any anticipated stretch!]

Circulating about the National Metal Congress in Chicago it takes no Walter Winchell to hear things about new combinations of steel deoxidizers and grain refiners that confer interesting — even remarkable — properties to low alloy steels. (Maybe this is one commercial application of the physico-chemical information gathered over the last decade about the action of minor elements on dissolved gases and carbides.) Time was, about a generation ago, when we talked about the action of silicon and manganese with considerable confidence. Aluminum was also used — rather furtively, for some fussy customers thought it was harmful. Then came vanadium and titanium with their grain-refining and toughening functions, calcium, zirconium, columbium — even nitrogen — all added on occasion to control oxygen, sulphur, carbon, grain size. The newest developments now utilize mixtures of three or more of these old and new metals in one ferro; they are added to steel made by alloy practice, timed as carefully as a European ultimatum. The result, at least in standard test pieces, is a fine-grained, tough steel, with good hardenability even with low alloy content — certainly a unique combination.

"gilding pale streams with heavenly alchemy . . . ."

For example, a manganese steel of the S.A.E. T-1300 series made in the conventional way may quench to C-25 at a point 1½ in. from the end in the Jominy test; treated with one of these new ferro-alloys, it might measure C-55 at the same place. After a low draw these new heat treated steels would have Charpy impact tests of 12 to 15 ft-lb. instead of about 5 ft-lb. normally expected of the manganese steels.

At one of the Welding Society's sessions, in discussing the cause of failure of the Hasselt bridge, Leon Rucquoi, director of the Institute of Steel Construction of Belgium and Luxemburg, not only put many an American to shame by his fluent and clear language but also gave us a definition of that baffling word "brittleness". This welded bridge (as described by Professor Portevin in Metal Progress's correspondence pages for May 1939) carried an important highway over a canal. It was designed by competent engineers, erected according to specifications, successfully withstood a proof load, was officially accepted by the Belgian Highway Department, served satisfactorily for a year and a half, when one day under practically

it was a brittle bridge

no load at all it broke up and fell into the canal in several pieces. "That", said M. Rucquoi, "was a brittle bridge!" . . . . . Its steel was made from the high phosphorus Minette ores by the basic bessemer process, as is more than half of the steel made in Belgium, France, Luxemburg and Germany. Immediately there was an outcry from openhearth steel producers that such an accident was no more than could be expected from bessemer metal. Therefore an extensive program of tests is now under way at the University of Liege to determine whether there is a consistent difference in the properties of welded joints made of killed or rimmed steels, bessemer or openhearth.

[Typographical and Esthetic Note — *L'Ossature Metallique*, a monthly review published by M. Rucquoi's organization, is quite the best looking of European magazines in the metallurgical field. We compliment ourselves by saying it is a little Metal Progress. Its advertising is all printed from one family of gothic type faces, strong and angular, thus giving the whole magazine an air and unity sadly lacking in American journals wherein the production of advertising experts and editors, jumbled together, vie with one another for the reader's attention — too often, perhaps, succeeding only in diffusing it.]

"Weldability" was a term purposely avoided in the last paragraph. But now that M. Rucquoi has so clearly defined "brittle", Walter Jominy of General Motors and others have pinned down the word "hardenability", and Orville Boston of Ann Arbor valiantly laboring on "machinability", the term weldability might as well be tackled — as indeed it was at a round table discussion organized by Mortimer Sayre of Union College for the American Welding Society. A grand time was had by all, with a lot of talk on and off the record. No one objected to the proposition that *any* respectable metal was weldable, given freedom of choice as to joint design, welding process, metal pre-treatment and post treatment. What is desired by the weldor, rather, is a test that has a closer relation to an actual joint or design, a commercial operating technique, available equipment, and the intended service. The present weldability test by the U.S. Navy makes the difficult Tee joint in plate of ordinary thickness and then finds out how much abuse it will stand by bending the sample in a fixture that throws tension in the fillets. Another routine described by James Hodge of Babcock & Wilcox is susceptible of quantitative evaluation and has been correlated with experience on the Boulder Dam penstocks; in this a bead is laid automatically on a plate of standard size, the welt machined off, the smooth plate bent (top down) and elongation measured when cracks appear. Another reasonable and simple test for weldability in an engineering structure would be to weld an actual joint under controlled conditions representative of shop practices and test the joint in bending for ductility, and impact for toughness. If the result comes to, say, 80% of parallel values for the original metal, the welded joint will be better than riveted or bolted joints we have endured so long. The metal would, in fact, be weldable.

weldability of metals

Back at home after a busy week at the National Metal Congress and Exposition (21st edition), reflecting that the Metal Show is getting too big for one man to absorb, lacking the ability to be in several places at one time. The ⛑ itself runs sessions simultaneously, or sessions or lectures during exposition hours; matters worth attention are multiplied by the technical and social activities of the three other collaborating societies. The indescribable exposition itself is, of course, the focus of interest; it is worth any firm's expense money. Then is the pleasant meeting of innumerable friends from all over the country, with their gossip and news and hints to solve your problems. Then is the Campbell Memorial Lecture, this year, as always, an account of fundamental metallurgical progress by a brilliant young engineer or scientist. Another high record of excellence for future years to shoot at was set by Bain's lectures on the function of alloying elements in steel, deservedly well attended, for they summarized an enormous amount of experimental and practical facts in a systematic way; the text should become a classic, a monument, a new starting point in the literature. It may be traitorous to write that these matters overshadow the many technical sessions because their really important contributions are not high-lighted among the number of other papers of less general interest.

ASMetal Congress and Expo

Special Refractories in melting furnaces

By J. B. Austin
Kearny, N. J.

"SPECIAL refractories" was the subject of the autumn meeting of the Refractories Division of American Ceramic Society held at Conneaut Lake, Pa. Although delayed in publication owing to conflict with the Annual Reference Issue of METAL PROGRESS, these desiccated statements suffice to give essential information about the meeting, tell the truth and nothing but the truth, yet they fall far short of the whole truth because they omit the fact that the meeting was attended by a large and enthusiastic group who heard an interesting collection of papers. The autumn meeting is by tradition devoted to a consideration of refractories from the consumer's point of view and the discussion is for that reason usually lively and varied. This year was no exception.

The term "special refractories" is somewhat vague and its limits vary with different people but broadly speaking it covers all refractories other than those made of silica, fireclay, chromite or magnesia alone. Combinations such as chrome-magnesia brick are at present generally considered as "special refractories", although it is likely that before long they may pass into common category.

Following a summary of the special refractories used in non-ferrous metallurgy, by Grant S. Diamond of Electro Refractories & Alloys Corp., Seaver H. Booth of the American Brass Co. discussed the "Refractories Used in Ajax-Wyatt Induction Furnaces Melting Copper, Brass, Nickel-Silver and Other Alloys".

For Non-Ferrous Use

He described the widespread use of these furnaces, estimating that about three quarters of all the copper and copper alloys to be used in rolling, drawing or extruding are melted in them, and ascribed their popularity largely to their simple construction and ease of operation. In fact, operation has become so simplified that a furnaceman is almost to be classed as unskilled labor. Fifteen years ago the use of induction furnaces was limited largely to alloys containing 80% or less of copper but improvements, chiefly in refractories, now make it possible to melt pure copper and nickel alloys in them. A leak due to a failure of the lining is relatively rare and when one does occur it can usually be traced to one of three causes — *(a)* the use of a ramming mix of poor

quality, *(b)* poor ramming or *(c)* severe abrasion. Refractoriness, though a necessary property, is not the only requirement; low permeability is also desirable since zinc vapor or copper oxide tends to pass through the lining and condense on cooler parts of the furnace. This not infrequently short circuits the coils. The best refractories for severe service, such as melting pure copper, appear to be an English patching cement containing 54% silica and 38% alumina, a highly aluminous material (80% Al_2O_3, 11.5% SiO_2), and mullite cement. Present practice calls for the use of a fresh lining on copper or high copper alloys until the furnace slot has been considerably opened up and then to melt alloys lower in copper until the slot begins to close; occasionally the furnace is then again used on copper. With this schedule the life of a refractory is considerably extended. In discussion Mr. Booth stated that in his opinion pre-fired refractory blocks appear to have no appreciable advantage over a good rammed lining.

The next paper — "A Study of the Effect of Aluminum on Refractory Brick", presented by H. O. Burrows of the Aluminum Co. of America — described a penetration test in which a large number of bricks were immersed for 35 days in a ladle containing molten aluminum at 1400° F. The bricks were placed so that the level of the molten aluminum came about 1½ in. from the top of the brick and an aluminum disk was placed on top of each so that the effect of the presence of air on penetration could be determined. The increase in weight of each brick was taken as a measure of penetration by the aluminum. The results showed, as might be expected, that in general the denser the brick the less the penetration. In many of the specimens penetration was different on the brand side from the opposite side, and some were severely attacked at the level of the liquid metal where aluminum and oxide were both present. A few bricks swelled noticeably and gave some indication of having been at a temperature appreciably above 1400° F., which might be interpreted as evidence of a thermit reaction — but the data are not conclusive, especially in view of the fact that such reactions commonly require a temperature well above 1400° F. to start them off. The iron content of the aluminum bath increased from 0.65 to 1.03% but much of this came from the iron tube protecting the control thermocouple. Silicon increased from 1.26 to 4.50%. No definite conclusion as to the best chemical composition was given, although it was stated that a high alumina-fireclay mixture was among the best of the materials tested. In discussion it was brought out that aluminum reacts readily with free silica but less readily with silicates. Silicon carbide pots are now replacing iron pots for melting high purity aluminum, but it has not yet been established that silicon carbide is generally superior to or more economical than iron for this purpose.

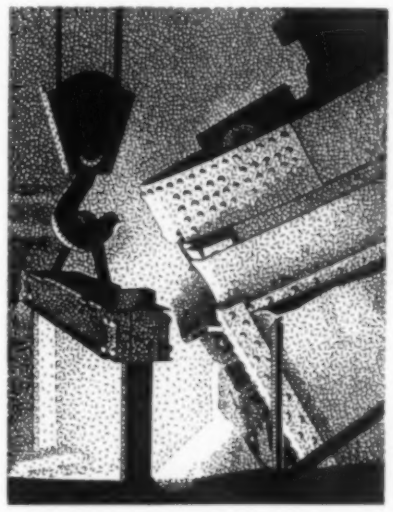
W. B. Boggs of Noranda Mines, Ltd., (Canada) then described the "Refractories in the World's Largest Copper Smelting Furnace". The Noranda furnace has sidewalls of magnesia with a suspended arch roof which is largely of the same material. The arch is some 5 ft. higher than the original sprung arch made of silica brick, which so increases the combustion space above the bath that 100% more coal can be burned. Consequently the capacity of this reverberatory furnace, which melts roasted calcines to copper matte for further converting by bessemerizing, has been increased from 500 to 1500 tons per day and the fuel ratio has been lowered from 15 to 10.4%. One of the most interesting features of this furnace is the construction of a lining for the sidewalls. Tin cans, 6 in. thick, 2 ft. wide and 3 ft. long are filled with magnesia and hooked to the skewback by eyebolts in the magnesia. Thus suspended the cans cannot fall into the furnace but can be replaced while the furnace is under full fire. The average life of such cans is about six months. Magnesia refractories are used extensively throughout the Noranda plant; the converters are lined with unfired magnesia and the furnace for casting bessemerized copper into anodes has a fused bottom of magnesia with 10% roll scale. When the latter furnace was increased in size the extra bottom required was made of magnesia and a rammed plastic chrome material.

For the Openhearth

A whole day was devoted to special refractories as used in the steel industry and the discussion was started by Louis A. Smith of the Jones & Laughlin Steel Corp. who spoke on "Refractories for the Openhearth". He believes that there is a growing trend away from the traditional burned-in bottom of magnesia toward plastic chrome materials, which in some cases may prove to be both cheaper and safer. There

is now in operation a furnace with a bottom of only 2 in. of magnesia backed by a 9-in. soldier course of chrome brick, and there is some talk of building a furnace with *no* magnesia on the bottom.

Reference was made to the controversy over the relative merits of European and American refractories, and in particular unfired magnesia brick, and Mr. Smith said that the steel maker should not avoid a promising material merely because the initial cost is high — and this in spite of what he termed the "classic example of the silicon carbide roof". There is a recent report about an Australian openhearth with a roof made of unfired magnesia brick costing $1.00 apiece, which stood up through two campaigns totalling 720 heats, and 75% of the brick are still in the roof during a third campaign! It is estimated that to date this has saved 20¢ per ton of ingots, and the operators state that they could have used a brick costing as much as $1.50 apiece and still come out ahead.



In an openhearth the most severe service in the roof is over the spout. In one furnace the use of metal-clad magnesia for some 3 ft. or so above the skewback has eliminated much trouble and patching in this location, but in other furnaces conditions may be such that there is no advantage in this construction. Because of the damage done by charging machines only a cheap material can be used in the front wall, which means that silica is to be preferred.

Mr. Smith described briefly some experience with an auxiliary burner made of silicon carbide in one of the ports. It was the only refractory tested which could stand the wear but it stood up very well. In a recent shutdown of the Jones and Laughlin pilot openhearth, which as described in METAL PROGRESS in May 1939 is a recuperative furnace, it was noticed that the bottom tubes of the silicon carbide recuperator were used up. This is not serious since they have plenty of recuperator capacity for the small furnace but it is felt that the same arrangement might not be successful in a large furnace.

In Mr. Smith's opinion we are coming to the use of a suspended roof over the open-hearth. It seems a needless waste to have to scrap so many roof brick every time a new roof is made, as is now necessary, and it should be worth while from that standpoint alone to use a suspended arch.

The anchor man on this team of speakers was Joseph A. Sarandria, Electro Refractories & Alloys Corp., who has been making a "Correlation of Physical and Chemical Properties of Stopper Heads with Openhearth Service". In his opinion the fundamental variables influencing the service of a stopper head are erosion resistance, porosity, melting point (pyrometric cone equivalent), cold fired strength, load bearing capacity, and thermal conductivity. Tests on a number of different kinds of stopper heads led to the following conclusions: Very high or very low porosity is detrimental to long service; the optimum is between 23 and 28%. Melting point is of secondary importance since failure by fusion is rare. The compressive strength should be above 2300 psi. The presence of graphite lowers the strength but increases the refractoriness. The diameter of the bolt head is a factor and should not be too small. Of the different grades of steel, those high in manganese are most severe on stopper heads. In discussion it was brought out that other deoxidizers used in the openhearth may likewise be hard on stopper heads.

For Electric Steel

Lead-off for this topic was B. W. Mogalis of Babcock & Wilcox Co. who discussed "Refractories used in High-Frequency Electric Melting of Steel and Alloys". He described three methods of building up the furnace lining. The first, often used with an acid lining, is to ram the refractory around a wooden core, which is then removed and the lining dried, as by inserting a carbon core and turning the current on. The second method of forming the lining is to use an asbestos cylinder closed at one end as a form around which is packed the lining, usually a basic material in this method. The first melt in the furnace destroys the cylinder which floats off as slag. A welded steel cylin-

der is sometimes used instead of asbestos but the steel occasionally splits. The third method which is applicable chiefly to small furnaces is to use a clay-bonded magnesia crucible around which magnesia flour is rammed. The chief special refractories used in linings are sillimanite, zircon ($ZrSiO_4$), a mixture of 40% alumina and 60% magnesia, and calcined alumina itself. Zircon has a tendency to be softened by iron oxide.

J. H. Chivers, in a discussion of "Refractory Life in Electric Arc Melting of Steel and Alloys", pointed out the differences between the openhearth and electric furnace which influence the life of refractories in the respective furnaces, chief among which are the time between heats and the time required for loading. "Superduty" fireclay refractories have some advantage in the electric furnace in spite of their higher cost. Magnesia is useful in the roof because it permits a higher temperature for refining and does not drip silica into the slag (which must be under close control). Chrome refractories are not ordinarily used because of the danger that spalling may increase the chromium content of the bath, but they have been successfully used in three 10-ton units exclusively melting high chromium alloys. Monolithic sillimanite has been successful in a one-ton furnace but might not prove so satisfactory in a larger one. One firm is using sillimanite brick around the electrodes and for the ring and spokes of the roof on a six-ton furnace. The use of carbon blocks has been discussed but there is little experience on which to base an estimate of their usefulness. Mr. Chivers emphasized that the voltage of the arc circuits has an appreciable influence on the life of refractories. In general the use of a high voltage raises the refractory cost, hence the voltage should be kept as low as is consistent with other requirements. There is working at present a 25-ton electric furnace with a conical shell which appears to offer advantages; others of this type and size are likely to be built.

Extra-Curricular Activities

Of the extra-curricular activities, the one attracting most attention was that H. M. Kraner of the Bethlehem Steel Co., in warming up for the golf tournament, made a hole in one — fortunately in the presence of unimpeachable witnesses.

Amorphous (?) metal

By Martin Seyt

EVER since metallographic observations have proven that solid metals are aggregates of tiny crystals, scientists have tried to correlate mechanical and physical properties of sizable metallic test pieces with the properties of single crystals, as modified by their boundary conditions. The transition regions within the metal where one crystal stops and another starts have been given especial attention. Rosenhain postulated that there the metal was truly non-crystalline. Beilby said that the increase in strength of metals on cold work was due to fragmentation of grains and concomitant increase in quantity of such amorphous boundary material, supposed to be stronger. Jeffries explained the experimental fact that metals generally break with a transgranular fracture at atmospheric temperatures but with intergranular fracture at somewhat elevated temperatures by assuming that the boundary material became weaker than the grains at temperatures above the "equi-cohesive".

Professor W. Lawrence Bragg of Cavendish Laboratory, Cambridge, England, returns to this general problem in a discussion on "The Structure of a Cold-Worked Metal" before the Physical Society. He rejects the hypothesis that there is any amorphous metal at grain boundaries more than two or three atom diameters in thickness, where they are simultaneously under the influence of at least two different orientations or types of crystalline arrangement. Atoms in the center of any macroscopic Beilby layer, being quite free to move, would immediately take up a regular crystalline form, interatomic forces between metal atoms being much less than those chemical bonds in a vitreous silica, for instance. Such atomic movements in solid metals actually occur, for diffusion in metal alloys occurs at temperatures as low as 200° C., which means that atoms drift over an enormous distance in comparison with the trivial readjustment needed to transform one arrangement of metal atoms into another. The latter proceeds even at sub-zero temperatures during the transformation of retained austenite in quenched alloy toolsteel by supercooling it in liquid air.

The urge of cold-worked metal to crystallize comes from the fact that 0.2 to 0.5 calories per gram are bound up with lattice distortion and intercrystalline boundaries in *(Cont. on page 656)*

Instant . . . CONTROL ACTION *by* RADIO IMPULSE

PRECISION WHEELCO INSTRUMENT
DEPRESS LEVER AT LEFT AND BRING POINTER TO 3 BY ROTATING KNOB AT RIGHT
DEGREES FAHRENHEIT
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Wheelco POTENTIOMETER (*Temperature*) CONTROLLER

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Instantaneous Control . . The pointer is not used mechanically in any way to make contact or *SET IN MOTION secondary mechanical apparatus of the instrument, which eventually causes control action, such as depressor bars, cams, levers, gears, etc.

No moving mechanical parts. Negligible maintenance.

Bulletin 3200 gives complete, detailed information on this new standard of temperature control.

*The "Radio Principle" incorporates no mechanical apparatus to be SET IN MOTION to eventually cause control —it actually and instantly causes complete control.

Wheelco Instruments Co.

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Amorphous metal

(Continued from page 654)

cold-worked metal, and this energy would be released by self-annealing. Self-annealing occurs to a certain extent, because it is apparently impossible to produce crystallites by cold working finer than about 10^{-4} cm. diameter. Persistence of differently oriented crystallites of larger dimensions must be due to the assumption of certains forms of dynamic stability by the boundaries — a hypothesis advanced by Prof. Bragg on the basis of Sykes' researches in the copper-gold alloy (Cu_3Au).

In this alloy four types of superlattice (noted by A, B, C and D) are essential to stability. "If a promontory of A extends into a region of B, it will shorten (because the atoms at the tip have more neighbors conforming to the B scheme than to the A) until the boundary is flat or has curvatures like bubbles in a froth. When three domains A, B and C meet along a line, this line moves about in the crystal until the angles between the transition layers are so adjusted that no one domain tends to grow at the expense of the others. Finally the whole settles down to equilibrium and once this is established it is of a very persistent type."

So much for stability of the boundaries. How about the fact that there is a lower limit to the cold-worked structure? Fragmentation by cold work will produce crystals of mixed size, but the smaller the random particle the more certain it will be to be entirely surrounded by material of another orientation and it would be promptly eaten up and disappear. Likewise if cold work would form a thin layer of domain A temporarily stable between two crystallites of orientation B, thermal fluctuations would cause its boundaries to wave about. "If at any point the film becomes momentarily so thin that the atoms at that part have a larger number of effective neighbors in the B scheme than in the A scheme, the film would burst and B would eat up A." Mathematically it can be shown that such action would occur with high probability up to a certain coarseness of crystallite size or thickness but the rate of growth rapidly slows down to almost zero.

All this is in harmony with the experimental fact that foreign atoms slow down the rate of self-annealing, for such foreign atoms will trend toward the boundaries, and are hard to move. However, it gives little direct comfort to the person who is attempting to answer the question "Why does cold work strengthen a metal?"

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A manufacturer of industrial haulage trucks, for example, was up against that very situation. The drive shafts of this equipment must stand considerable abuse. Quick acceleration and sudden stops are the rule rather than the exception. And space is at a premium.

This manufacturer found in Nickel-Chrome-Molybdenum steel exactly the qualities required — high strength, which permits relatively small section, plus an exceptional combination of toughness, ductility and fatigue strength. The machineability of this steel in the heat treated condition keeps fabrication costs down.

It will pay you to re-check your material specifications in the light of present knowledge of the qualities and characteristics of Molybdenum steels. Our helpful book, "Molybdenum in Steel", is sent free to interested production executives and engineers on request.

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MOLY

Personals

Installed as president of the American Society for Metals at the recent convention in Chicago: **James P. Gill**, chief metallurgist, Vanadium-Alloys Steel Co., Latrobe, Pa. **Oscar E. Harder**, assistant director, Battelle Memorial Institute, Columbus, Ohio, has been made vice-president, and **Kent R. Van Horn**, research metallurgist, Aluminum Co. of America, Cleveland, has been made treasurer. Two new trustees are **H. J. French**, in charge of alloy steel and iron development, International Nickel Co., New York, and **Marcus A. Grossmann**, director of research, Carnegie-Illinois Steel Corp., Chicago.

John Welchner, formerly metallurgist for the Wisconsin Axle Division of the Timken-Detroit Axle Co., is now at the University of Michigan doing graduate work in special phases of metallurgy.

A. J. Fazio, day superintendent for the Braeburn Alloy Steel Corp., has recently been appointed assistant general superintendent in charge of all day and night shifts.

Awarded the Henry Marion Howe Medal for the best paper published in the *Transactions* during the preceding year: **Charles S. Barrett**, Carnegie Institute of Technology, **Gerhard Ansel**, Dow Chemical Co., and **Robert F. Mehl**, Carnegie Institute of Technology, for their paper entitled "Slip, Twinning and Cleavage in Iron and Silicon Ferrite".

"In recognition of his pioneering metallurgical achievements which have stimulated organized work along similar lines to such an extent that a marked basic advance has been made in metallurgical knowledge", **Stanley P. Rockwell** was presented the Sauveur Achievement Award of the American Society for Metals at the annual banquet held during the National Metal Congress in Chicago last month.

E. L. Reed, research metallurgist, Watertown Arsenal, Watertown, Mass., is now conducting the Sauveur and Boylston Correspondence Course in the Metallography and Heat Treatment of Iron and Steel.

Ralph K. Clifford, works manager of the Kokomo Division of the Continental Steel Corp., has been named vice-president in charge of operations for all of the company's plants, at Kokomo, Indianapolis, and Canton.

R. W. Emerson has been transferred from research engineer, Westinghouse Research Laboratories, East Pittsburgh, to development engineer, welding electrode laboratory, Westinghouse Electric & Mfg. Co., Trafford, Pa.

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Cleveland Hardware & Forging Co.....
.....Cleveland, Ohio
Muehlhausen Spring Corp....Logansport, Ind.
Allis-Chalmers Mfg. Co. .....LaPorte, Ind.
Forest Gear & Machine.....Jackson, Mich.
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Inland Mfg. Div. .....Dayton, Ohio
Muncie Products Div. .....Muncie, Ind.
Fred A. Snow Co. .....Chicago, Ill.
Timken Roller Bearing Co....Columbus, Ohio
Burgess-Norton Mfg. Co.....Geneva, Ill.
Cadillac Motor Car Co.....Detroit, Mich.
Dodge Main Plant.....Detroit, Mich.
National Lock Washer Co....Milwaukee, Wis.
Olds Motor Works.....Lansing, Mich.
Wyman-Gordon Co. .....Worcester, Mass.
International Harvester Co.....Several places
Jeffrey Mfg. Co.....Columbus, Ohio
Automatic Spring Coiling Co.....Chicago, Ill.
Chevrolet Gear & Axle Co.....Detroit, Mich.
Bendix Products Corp.....South Bend, Ind.
Eaton Mfg. Co. .....Detroit, Mich.
Liberty Foundries Co. .....Rockford, Ill.
Oliver Farm Equipment Co. .....
.....Charles City, Iowa
Wisconsin-Appleton Co. ..S. Milwaukee, Wis.
Fafnir Bearings Co. .....New Britain, Conn.
Detroit Gear & Machine Div...Detroit, Mich.
Cleveland Wire Spring Co.....Cleveland, Ohio
J. P. Danielson Co., Inc.....Jamestown, N. Y.
Lindberg Steel Treating Co.....Chicago, Ill.
Mechanics Universal Joint Co...Rockford, Ill.
Ontario Steel Products Co., Ltd.....
..... Oshawa, Ontario
Perfection Tool & H. T. Co.....Chicago, Ill.
Wallace Barnes Co. .....Bristol, Conn.
Auto Specialties Mfg. Co.....St. Joseph, Mich.
Delta File Works.....Philadelphia, Pa.
Bridgeport Hardware Co.....Bridgeport, Conn.
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Personals

Elected president of the American Welding Society: **George T. Horton,** president, Chicago Bridge & Iron Co. **T. C. Smith,** structural engineer, General Petroleum Corp., is first vice-president and **L. S. Moisseiff,** consulting engineer, second vice-president. District vice-presidents are **W. F. Hess,** instructor, Rensselaer Polytechnic Institute, for New York and New England; **L. C. Bibber** ⊜, welding engineer, Carnegie-Illinois Steel Corp., for the middle east; **K. L. Hansen,** consulting engineer, for the middle west; **A. J. Moses,** general manager, Combustion Engineering Co., Inc., for the southern district, and **L. W. Delhi,** Western Pipe & Steel Co., for the Pacific Coast. Directors-at-large are **E. V. David,** Air Reduction Sales Co.; **J. D. Gordon,** Taylor Winfield Corp., **G. F. Jenks** ⊜, Ordnance Department U. S. Army, and **H. S. Smith,** Union Carbide and Carbon Corp.

Harry S. Blumberg ⊜ was the main speaker at the opening fall meeting of the Ontario Section of the Institution of Mechanical Engineers in Toronto, Oct. 12.

William A. Mader ⊜ has left the War Ordnance Office, Philadelphia District, to become affiliated with the American Manganese Steel Co., Chicago Heights, Ill., as metallurgist.

Newly elected officers of the Metal Treating Institute, Inc., are: For president **A. M. Cox** ⊜, president, Pittsburgh Commercial Heat Treating Co., Pittsburgh; for vice-president **C. I. Wesley** ⊜, president, Wesley Steel Treating Co., Milwaukee; for secretary-treasurer **L. A. Lindberg** ⊜, vice-president, Lindberg Steel Treating Co., Chicago. New directors are **W. F. Hamilton,** president, Accurate Steel Treating Co., Chicago; **C. G. Heilman** ⊜, president, Commonwealth Heat Treating Co., Detroit; **O. T. Muehlemeyer** ⊜, president, O. T. Muehlemeyer Heat Treating Co., Rockford, Ill.; **C. W. Derhammer** ⊜, president, Lakeside Steel Improvement Co., Cleveland.

Chester W. Ruth has been appointed director of advertising of Republic Steel Corp., succeeding **Stanley A. Knisely,** who resigned to become executive vice-president of Associated Business Papers, Inc. Taking Mr. Ruth's former position as assistant director of advertising is **Harold H. Oldham,** heretofore manager of the copy and production departments.

To care for the increasing physico-chemical work in its varied sponsored projects and fundamental investigations, Battelle Memorial Institute has added to its supervisory staff **Edward Mack, Jr.,** formerly head of chemistry at University of North Carolina.

CONTINENTAL
lifts its
"TOP HAT"

Cover Annealing improvements featured by CONTINENTAL'S "Top Hat" Furnace:

UNIFORM ANNEALING — *because* radiant wall covered from top to bottom with continuous HEAT RINGS gives an unequalled heat distribution. Heating "from the inside out" is available with CENTER RADIANT WELL.

QUALITY MEETING EXACTING DEMANDS — *because* temperature distribution is uniform, it may be held to the accuracy of the best control instruments. Our furnaces accomplish this *with* or *without* fans.

UNUSUAL ECONOMY — *because* low priced gas fuel, all-over heat blanket, and flexible range of fuel input all give efficient operation.

A quarter of a century of continuous progress insures the efficiency and success of the CONTINENTAL "Top Hat" Furnace and all other CONTINENTAL installations.

Write for our bulletin No. 118 on this interesting COVER ANNEALING Furnace...TODAY.

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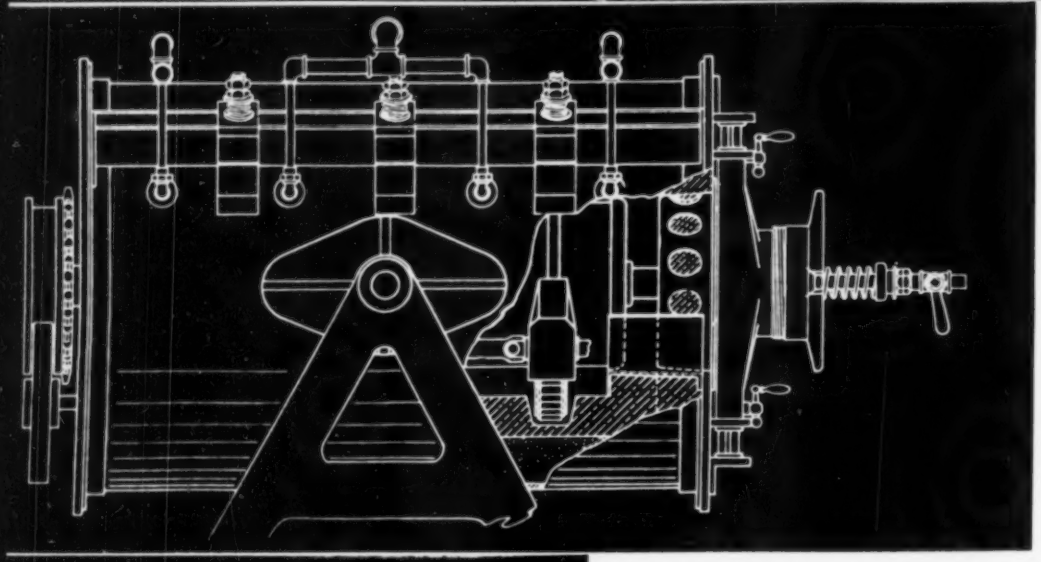
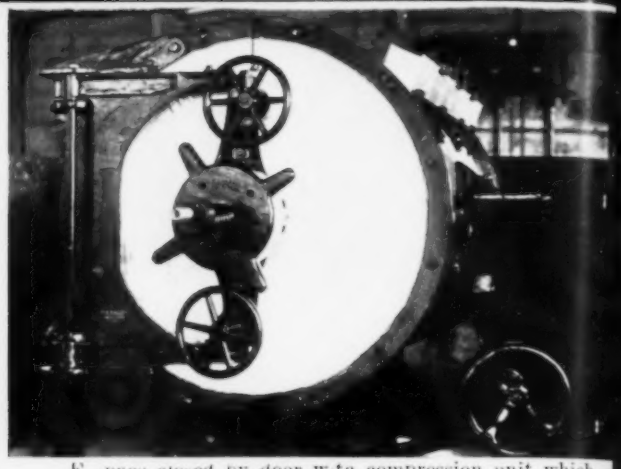
201 NORTH WELLS STREET, CHICAGO, ILL.

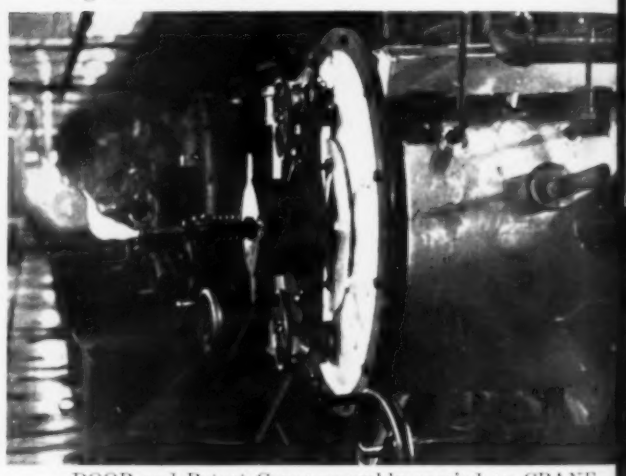
Announcing a new *Engineering Development*

OF VITAL IMPORTANCE TO EVERY OWNER OR PROSPECTIVE PURCHASER OF ANY ROTATING RETORT FURNACE

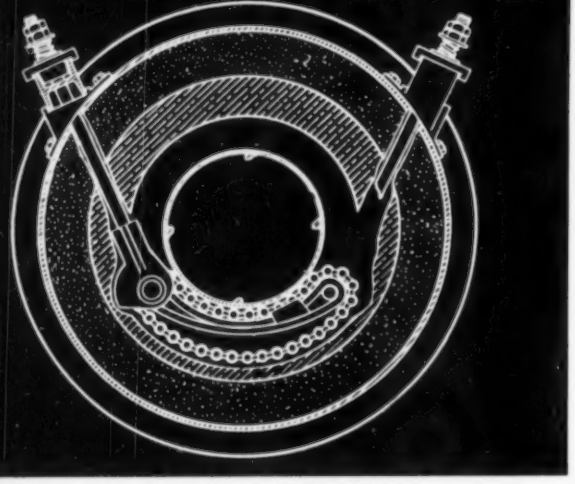




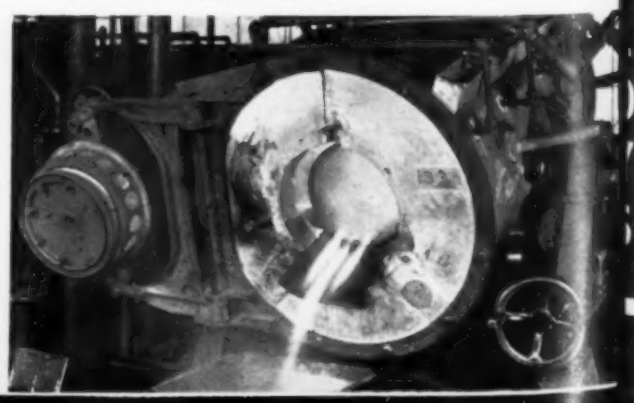
Furnace closed by door with compression unit which keeps retort cover tight, and permits eccentric motion against ball thrust.



DOOR and Retort Cover assembly carried on CRANE HINGE, on OILITE BEARINGS. DOOR and COVER swing out with cold side always toward operator. Open or close in 20 seconds.



"Caterpillar" HOT Roller Bearing runs on a "Sling" race of ⅝"x3" Q ALLOY bar, doubled to form closed loop. It is SELF-CONFORMING to Retort. ALL Rollers turn. LONG LIFE ROLLING FRICTION.



Lower view of furnace dumping shows door turned out to show cover. (Normal position of open door and cover in upper view.)

"EQUI-TEMP" RETORT
and Furnace Conversion Unit

THE Furnace illustrated is a standard old-type gas carburizing furnace equipped with the "EQUI-TEMP" Retort, rotating on 3 HOT "Caterpillar" ROLLER Bearings within the furnace. The furnace is fitted with a door carrying the retort cover, the latter rotating with the retort. This is a co-operative development, inspired by the Metallurgical Department of the Timken Roller Bearing Company, the first objective of which is METALLURGICAL IMPROVEMENT by closer case control. Reduced heating and carburizing time, increased production, fuel savings and alloy savings are by-products which add up to GREATLY REDUCED COSTS.

THE Retort weight is REDUCED from 685 lbs. to 345 lbs. with no reduction in guarantee. The "Plug" is replaced by a cover weighing 50% less. Machining is largely eliminated. While the form of the "Bottle-neck" is retained to permit use of the original drive sprocket, it is reduced from 1" to ⅜" in wall section. The rear outside support rollers CARRY NO LOAD, but act as thrust bearings only, the face of the old wheel on the sprocket being faced off ⅜ diameter for clearance.

THE door and retort lid swing as a unit on a quick-acting crane hinge, and can be opened or closed in 20 seconds. THE OPERATOR FACES THE COLD SIDE. THERE IS NO HOT PLUG TO HEAT-TREAT THE HEAT-TREATER.

THE conversion unit is easily installed;—drill some holes, tap some of them, chip out channels for the bearings in the inner lining, and cement the rough edges to size on a wooden template.

AS a TEMPORARY EXPEDIENT we have arranged for the manufacture of all these conversion parts to be sold complete with retort, fully guaranteed by General Alloys.

"EQUI-TEMP" Engineering can be applied to any Gas, Oil, or Electric retort furnace, to great advantage. We are negotiating with Furnace Builders to incorporate "EQUI-TEMP" features in their new furnaces. Inquiries from Gas Companies, Furnace Agents, and *FROM YOU*, ARE SOLICITED.

GENERAL ALLOYS CO.
BOSTON, U. S. A.

PATENTS PENDING on these and several other H.H.H. designs of Retorts, retort closures within furnaces, co-related furnace doors and retort covers, support bearings, hot roller bearings, bearing load equalizing devices, etc. *Infringers will be prosecuted.*

"EQUI-TEMP" retort comes to heat in 3 hours from cold with full load. Case depth can be controlled to two thousandths as against a common variation in old retorts of ten to twenty thousandths. The extra-capacity burners on the front end "To heat the cold end, which heats the heat-treat" can be saved. READ MORE ABOUT "EQUI-TEMP" on the opposite page.

NO FURNACE IS BETTER THAN ITS ALLOY PARTS

GENERAL ALLOYS EXHIBIT AT NATIONAL METALS EXHIBITION, CHICAGO, 1939

SOME thought the most eloquent Q-Alloy and X-Ite castings exhibited were those veterans of 5 to 16 years service borrowed from production use from the largest alloy installations in the Chicago district which are predominantly Q-Alloy. Others, accepting Q-Alloy and X-Ite service as a matter of course, were more impressed with the "EQUI-TEMP" Retort, the New Baby "SPIRALINK", and the "Hot Buggy" roller tray which holds all records for light weight trouble-free short cycle malleable performance in the Jamestown Malleable Iron Co. Surface Combustion Furnace. Over 50 new items of alloy engineering covered by H.H.H. Patents issued or Pending, ranging from hot roller bearings to 40% lighter carburizing containers and improved combustion tubes were shown. But easily the outstanding alloy exhibit at the show was the Q-Alloy retort in the new "VAPO-CARB" Carburizing Furnace at the Leeds and Northrup Booth, which is a prime example of engineering versus price-per-pound alloy buying and sets new standards. We leave our reputation in the hands of any man who compared G. A.'s exhibit at Chicago or any place else with temporary alloy exhibits.

IF you need a laugh look up Mr. Go in the Chicago telephone directory.

NO engineering Alloy design, having general application, ever offered has created so much interest or comprises such technical advance in one package as the "EQUI-TEMP" Retort illustrated on the opposite page, concerning which we comment further.

LONG, long ago engineering compromise dictated the grotesque necessity of elongating a red hot tubular beam (called a retort) in inverse ratio to its load-carrying capacity, so that the ends could be carried outside the furnace for support.

THE metallurgical monstrosity of one piece of metal running red in the middle—black at the ends—with sharp lines of temperature demarcation in a few inches—while subjected to stress reversals—was a *by-product*.

ANOTHER unwelcome step-child was the unavoidable use of 20 to 50 square inches of alloy cross section as a direct conductor of precious heat—from where you want it to where you don't want it—and wasting such heat through several square feet of area—like pouring water into a toeless boot.

TO the credit of all contributing to this outstanding development of its time—such retorts have,—when made heavy enough,—done a remarkably good job under most difficult conditions,—paid for themselves many times over. But,—so did the Ox Cart.

SUCH compromise is *no longer necessary*. To the splendid work which has gone before,—we add our modest contribution;—*the "EQUI-TEMP" Retort and Conversion Unit.*

GENERAL ALLOYS CO.
BOSTON, U. S. A.

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*A precocious brat, he ran a section on a western railroad, operated a Colorado Pierce-Arrow, and Premier Agency, exploited calorizing with the Diamond Power Specialty Co. and was Gen. Sales Mgr. of Swedish Crucible Steel Co. exhibiting for them at the first A.S.S.T. show in Chicago where Bell and Gossett Co. became the first agent for Q-Alloys which trade name was applied to H.H.H. Alloys, started as a department of Quigley Furnace Specialty Co., and thus exhibiting at the Philadelphia show. Buying Quigley's interest H.H.H. personally owned and operated G. A. Co. in Chicago until its incorporation in Boston, 1923, a move necessitated by the need for New England craftsmanship.

Co-incidental with business interests, studied Engineering and Metallurgy at Wisconsin and elsewhere, enlisted during war-to-end-war in U. S. Air Service, completed Aviation Ground School at U. of Ill., and "fought the battles of Texas".

Still crouching with feline impatience at the rat-hole of knowledge, and peddling alloys. Inquiries respectfully solicited.

20 YEARS CONSECUTIVELY

DURING the past 20 years that we have been the largest exhibitors in our line at the A.S.M. and A.S.S.T. shows, much of American metallurgical history has been made.

IT has been a great privilege to know most of the men who have built American metallurgy to world leadership, to watch their progress in the quest of knowledge and against the economic tides. We have known school boys who became "Medalists"; seen obscure metallurgists break through the prejudice against trained men to reach the top flight of American Management.

THIS is a glorious march of progress, carrying men of A.S.M. to distinction, with hundreds of thousands of other men, from workmen to bond-holders, riding in the great Van of Metals PROGRESS.

OUR greatest pleasure—our richest reward—has been to meet hundreds of these men each of these 20 years and hear some fragment of each man's story, from his own lips, above the handclasp of a friend. Keeping step with this leadership is a glorious adventure. All have contributed something. The smallest man in the rearmost rank has made his contribution, even if as a static milestone to mark the advance of others.

OF small significance, except to this writer, came his 40th birthday, at the Chicago Show, during his 21st year as an Exhibitor.*

IT is fun growing old in such good company despite the burden of educating economic and technological illiterates in the alloy industry. They say "Life Begins at 40"; if so, we start even, for it owes us nothing. We fly into the future with faith, hope and increasing charity.

HEAT resisting alloys are coming of age, too, and we strive to expedite their transition, already well underway, from a jobbing foundry business to largely standardized simple mechanism which the average engineer can turn to—like a link belt catalogue—without risk of joining the ranks of the too many amateur alloy designers still detracting from the potential reliability of mechanical furnaces and alloy installations generally.

WE have grown with A.S.M. and A.S.S.T. We have tried to reciprocate *their support* with 20 years of educational alloy exhibits, accepting the responsibility of accompanying the leadership of an industry. Appreciation of our efforts has been gratifying.

A.S.M. individually and collectively MOVES ON to new and greater achievement as each sunrise unfolds broader opportunity and each sunset confirms Metal PROGRESS. We're glad to be along! H.H.H.

THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

GA X-ITE GA Q-ALLOYS GA X-ITE GA Q-ALLOYS

B&L Spectrographic Methods *PAY DIVIDENDS*

SPECTROGRAPHY simplifies analytical procedure—speeds up the solution of many research and control problems.

B&L Spectrographic Equipment brings to the practising spectrographer these many advantages—increased precision and sensitivity in qualitative and quantitative work, adaptability to new uses and domestic availability of accessories, parts and service.

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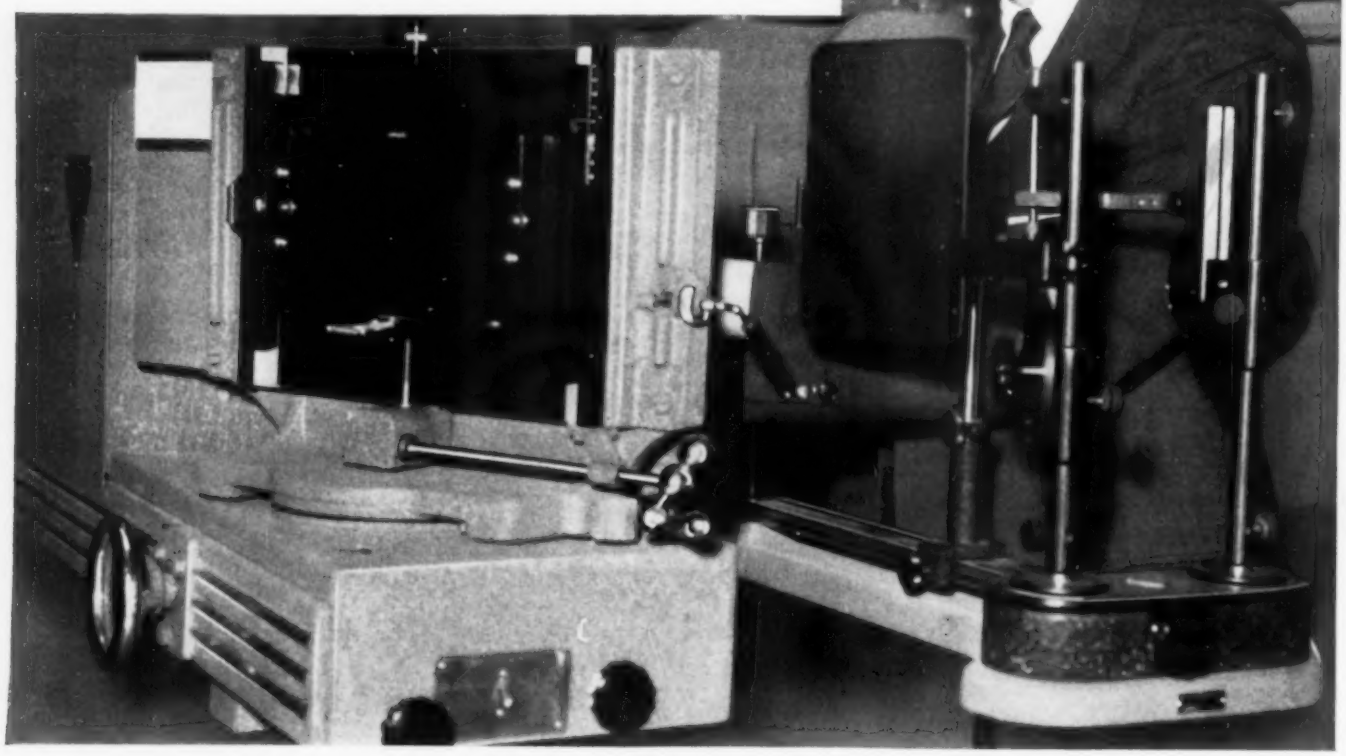

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WESTINGHOUSE HARDENS ALL S. A. E. STEELS *without "Decarb"*

Here's the Proof for Spring Steel S. A. E. 6150

Magnification 500X — Unretouched

1. ORDINARY SCALE-FREE HARDENING SHOWS DECARBURIZATION OF .005 INCH. Upper, white portion of micro-section No. 1 shows how heat treatment in ordinary scale-free atmosphere, at 1500° F. for one hour, removed carbon from S.A.E. 6150 Spring Steel to a depth of approximately .005 inch.

2. WESTINGHOUSE SCALE-FREE HARDENING SHOWS NO "DECARB." Micro-section No. 2 shows conclusively that no decarburization takes place when S.A.E. 6150 Spring Steel is heat-treated in the new Westinghouse ENDOGAS atmosphere. Treatment was at 1500° F. for one hour, the same as in case No. 1.

Now you can harden or anneal any S.A.E. steel and have it completely free from decarburization — as in the case above — if you use the newly developed Westinghouse ENDOGAS atmosphere. Micro-photographs of results achieved on a number of steels formerly considered difficult to treat — including S.A.E. 1095, 6150 and 52,100 — have proved the superiority of this method under actual production conditions.

The Westinghouse process is not expensive. The ENDOGAS atmosphere — high in CO and low in CO_2 — is obtained by starting with either natural or manufactured city gas. Costly driers and CO_2 removal equipment are not required.

WRITE TODAY FOR COMPLETE INFORMATION

This new process for scale-free hardening or annealing, without decarburization, is a low-cost method of increasing product quality and uniformity. It will pay you to get in on the "ground floor" by writing today for complete details. No obligation. Just address Dept. 7-N, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

J-10149

Westinghouse

Complete Heat Treating Equipment

DR. EDGAR C. BAIN

Assistant to the Vice President of the
U. S. Steel Corporation

PRESENTS HIS BOOK

FUNCTIONS *of the* ALLOYING ELEMENTS *in* STEEL

The largest group of men ever to register for an ASM educational course heard Dr. Edgar C. Bain, noted metallurgical authority of the U. S. Steel Corp., deliver his five lectures on "Functions of the Alloying Elements in Steel" at the Chicago National Metal Congress.

Their enthusiastic reception of Dr. Bain's remarks on carbon steels . . . alloying elements . . . hardenability . . . tempering, was a tribute to the painstaking effort which went into this series. Dr. Bain presents his material in concise, clearly understandable language—making simple a subject which is of fundamental importance to every member of the American Society for Metals.

If you were one of the four or five hundred men who gathered daily to hear these lectures during the Metal Congress you will be glad to learn that the complete series is now available in a well-made, 6x9 book containing 312 pages with 186 interesting illustrations. Until December 15 this book will be sold at the introductory price of $3.00 per copy. (After this date $4.00.)

And if you didn't get to the Metal Congress, you will treasure this book more than ever . . . for it brings you first-hand information on this important subject from one of the most respected authorities in the metal industry. Use the handy coupon below to send for your copy TODAY.

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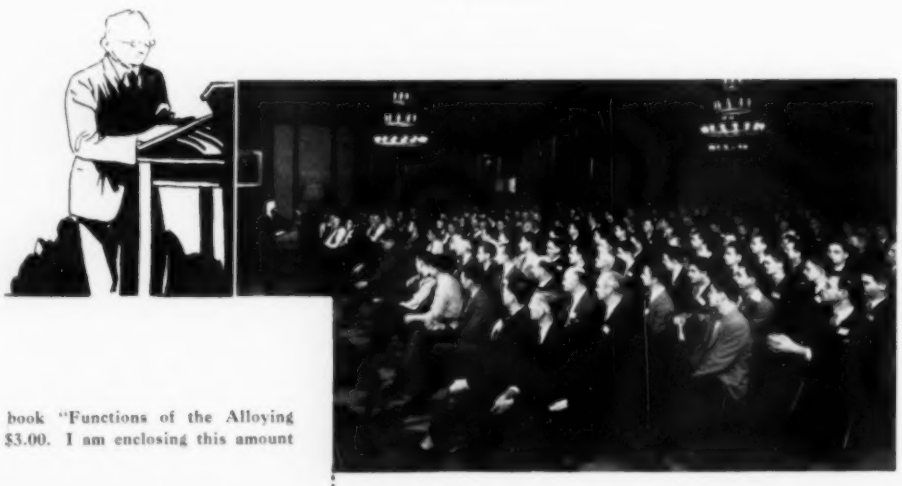
BEFORE DEC. 15



Shown at the left is a typical group listening to Dr. Bain present his educational series at the recent Chicago Metal Congress.

merican Society for Metals, 7016 Euclid Avenue
leveland, Ohio
entlemen:

Please send me a copy of Dr. Edgar Bain's new book "Functions of the Alloying lements in Steel" at the special introductory price of $3.00. I am enclosing this amount cash ( ), money order ( ), check ( ).

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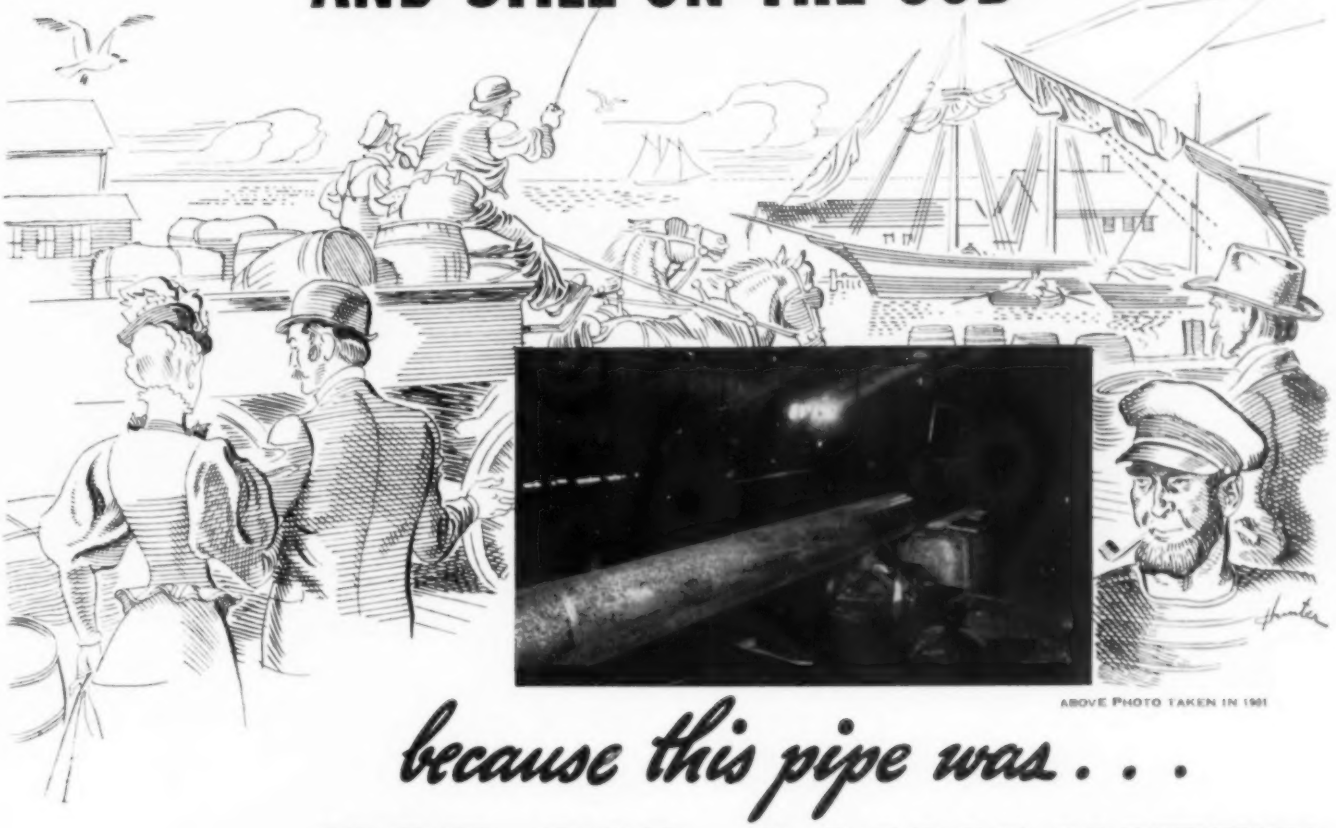
In the depths of San Francisco Bay for 37 years

AND STILL ON THE JOB



ABOVE PHOTO TAKEN IN 1901

because this pipe was . . .

HOT DIP GALVANIZED

People often ask, "How long will Hot Dip Galvanizing last?" That we cannot answer; but one example is the pipe above laid across the bottom of San Francisco Bay in 1902 and still in good condition. The cost of Hot Dip Galvanizing it was small but the cost of repairing or replacing it would be tremendous . . . to say nothing of the serious trouble that would have occurred had it failed in its duty of supplying water to the people of this city . . . Where rust is a factor, nothing serves so long for so little as Hot Dip Galvanizing because only the **hot dip** process guarantees an adequately thick coating of zinc and a **union** between zinc coating and base metal that makes each an **inseparable** part of the other. **Patronize** members of this association and **know** that you are getting **perfect** workmanship and **genuine** Hot Dip Galvanizing on every job . . . Let us send you literature. Address American Hot Dip Galvanizers Association, Inc., American Bank Building, Pittsburgh, Pa.

IF IT CARRIES THIS SEAL IT'S A JOB WELL DONE

No. 1 in a series of advertisements featuring the service histories of various Hot Dip Galvanized products . . . FROM OUR FILES—CASE NO. 0937. Water Tube Hot Dip Galvanized by JOHN FINN METAL WORKS, San Francisco—1901.

Acme Galvanizing, Inc., Milwaukee, Wis. ★ Acme Steel & Malleable Iron Works, Buffalo, N. Y. ★ American Tinning & Galvanizing Co., Erie, Pa. ★ Atlantic Stamping Co., Rochester, N. Y. ★ Buffalo Galvanizing & Tinning Wks., Inc., Buffalo, N. Y. ★ Columbian Steel Tank Company, Kansas City, Mo. ★ Diamond Expansion Bolt Co., Inc., Garwood, N. J. ★ The Fanner Mfg. Company, Cleveland, Ohio. ★ John Finn Metal Works, San Francisco, Cal. ★ Thomas Gregory Galvanizing Works, Maspeth, N. Y. ★ Hanlon-Gregory Galvanizing Co., Pittsburgh, Pa. ★ The Hodell Chain Company, Cleveland, Ohio. ★ Independent Galvanizing Co., Newark, N. J. ★ International Derrick & Equipment Co., Columbus, O. ★ Joslyn Co. of California, Los Angeles, Cal. ★ Joslyn Mfg. & Supply Co., Chicago, Ill. ★ L. O. Koven & Brother, Inc., Jersey City, N. J. ★ Lehigh Structural Steel Co., Allentown, Pa. ★ Lewis Bolt & Nut Company, Minneapolis, Minn. ★ Missouri Rolling Mill Corp., St. Louis, Mo. ★ The National Telephone Supply Co., Cleveland, Ohio. ★ Penn Galvanizing Co., Philadelphia, Pa. ★ Riverside Foundry & Galvanizing Co., Kalamazoo, Mich. ★ San Francisco Galvanizing Works, San Francisco, Cal. ★ The Sanitary Tinning Co., Cleveland, Ohio. ★ Standard Galvanizing Co., Chicago, Ill. ★ Wilcox, Crittenden & Co., Inc., Middletown, Conn. ★ The Witt Cornice Co., Cincinnati, Ohio.

Contributors

Knowing the telephone inside-out is no mean accomplishment, for a great deal of complicated and delicate mechanism is crowded into the transmitter itself as well as contained in the electric wire jungles of the exchange offices. **Earle E. Schumacher** and **W. C. Ellis**, however, have a more than adequate background for the task of describing the metals used in telephones and auxiliary equipment. Schumacher, who is research metallurgist, a graduate of the University of Michigan, has been with the Bell Telephone Laboratories for better than 20 years. He has studied many different metallurgical problems and has published numerous technical papers dealing with his researches.

Ellis was graduated from Rensselaer Polytechnic Institute in 1927 and has been at the Laboratories ever since. His main field of study covers magnetic materials and conductor alloys.

Edmund S. Davenport, whose lucid Campbell Memorial Lecture given at the National Metal Congress last month is in extended abstract beginning on page 623, is perhaps the closest collaborator with Dr. Bain in the now-famous researches carried on by U. S. Steel Corp. which resulted in the formulation of the "S" curve and a new concept of steel metallography. Mr. Davenport has been in charge of the metallurgical work at the Steel Corporation's central research laboratories since 1935. Educated at Yale's Sheffield Scientific School (Ph.B. in chemistry, 1919, and M.S. in metallography, 1921), he spent a year as research metallurgist for Eastern Malleable Iron Co., Naugatuck, Conn. From 1922 until he joined the Steel Corp. in 1929 he was metallurgist for Westinghouse Lamp Co. In 1931 he received the Robert W. Hunt award of the American Institute of Mining and Metallurgical Engineers, and he is currently chairman of the large and active New Jersey Chapter.

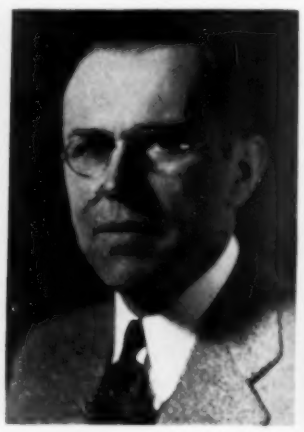
The modern convection heating units described on page 637 are a far cry from the furnace **Edward Stephenson, Jr.** worked with when he joined Surface Combustion Corp. 20 years ago. He has taken part in furnace developments with this same organization ever since, and is now combustion engineer in the Detroit district. His earlier connections in the metal industry were with Shelden Axle and Spring Co. and Willys-Overland Co. He is a graduate of Pennsylvania State College.

The last time **Robert G. N. Evans** appeared as an author in METAL PROGRESS (July 1938) he was engineer in charge of research for Bunting Brass and Bronze Co. of Toledo, Ohio. He has now established a consulting practice of his own in Milwaukee, specializing in problems concerning sleeve bearings, non-ferrous metals, surfaces and lubrication technology. His interest in bearings started with an interest in automobiles, first as a racing driver, then as service engineer with Paige Motor Car Co. During the War he supervised a forge plant for the Army, then engaged in consulting work until he joined Bunting in 1928.

J. B. Austin's vivacious accounts of the meetings of the American Ceramic Society's Refractories Division are a regular feature of METAL PROGRESS, four of them having been published since his first reportorial venture in May 1937. At the U. S. Steel Corp. Research, where he has been for ten years, Austin divides his time about equally between metals and refractories.

Edmund S. Davenport

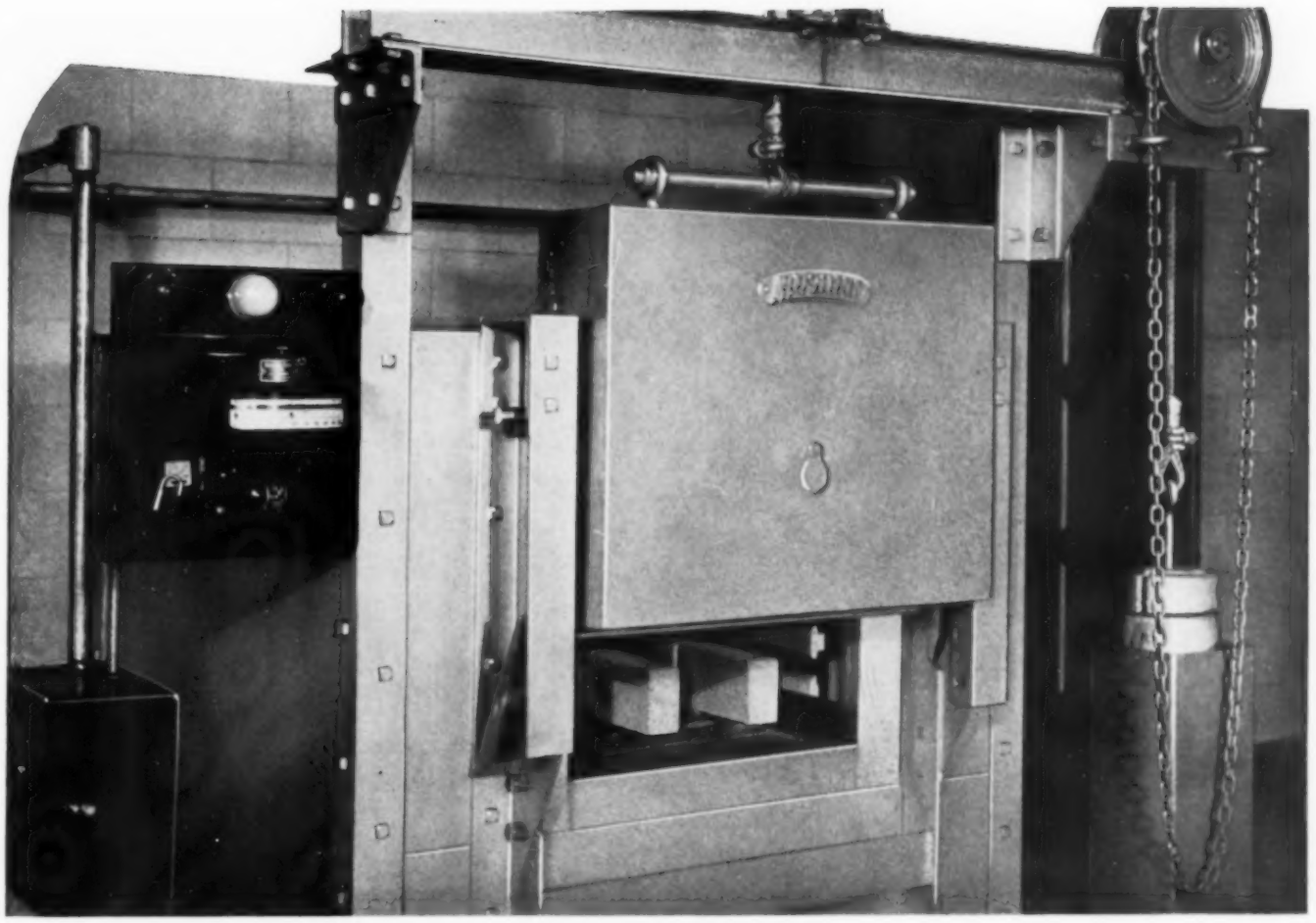
Earle E. Schumacher



Edward Stephenson, Jr.

Robert G. N. Evans

J. B. Austin



HELP TO INDUSTRY THROUGH RESEARCH

For good heat resisting castings, rightly designed, and priced—for furnace parts, boxes, pots, etc.—send for folder, "Every Shape and Form."

Mellon Institute of Industrial Research does what its name suggests—works successfully on the technical problems of industry. On many of these projects, they find this Hoskins Electric Furnace useful. . . . Laboratory and plant like Hoskins Furnaces because they deliver all the many advantages of electric heat. The Chromel elements are strikingly durable and easy to renew. The furnaces vary in size and type—one of which will do what you have in mind, in a better way. Ask for Catalog 57 . . . Hoskins Manufacturing Co., Detroit, Mich.

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AB

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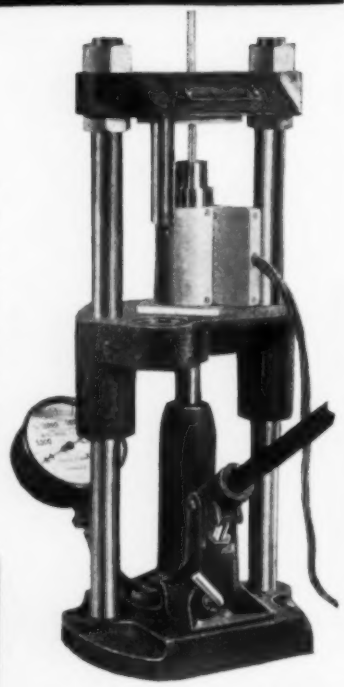
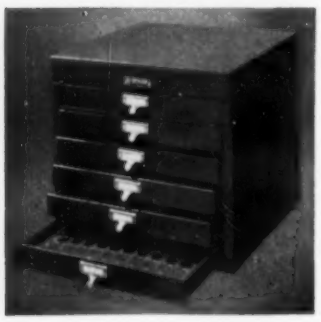
Pioneers a new technique for the metallurgist, and solves the problem of specimen mounting. It eliminates differential etching action frequently encountered with fusible alloys. The advantages of extreme edge studies, convenience in handling, speed and economy, contribute to the popularity of the new AB Specimen Mount Press.





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The dream of the metallurgist became true with our introduction of the transoptic mounting technique. For visibility of specimen from all sides, for ease in making electrical connections in electrolytic etching, Transoptic mountings are a definite step forward.

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Forging stock waiting on shear blades being ever-lastingly reground—drop hammers waiting for stock—customers bellowing.

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"Good salesmanship is selling goods that will not come back, to customers that will."

MAURATH, INC., CLEVELAND

BUILDER OF BETTER WELDING ELECTRODES IN ALL ANALYSES

HELPFUL LITERATURE

Spectrometry

A chapter on basic theory and design of spectrometers or spectrographs explaining the principle of operation in full detail precedes a catalog of spectrometric equipment by Bausch & Lomb Optical Co. Bulletin Fa-35.

X-Ray Examination

The application of X-ray examination and inspection of castings, welding, and food products, as well as practical X-ray crystal analysis, is completely described and strikingly illustrated in General Electric X-Ray Corp.'s 34-page publication. Bulletin Dy-6.

Testing Catalog

A loose-leaf binder provides a handy reference catalog of testing machines made by Steel City Testing Laboratory. Universal hydraulic machines, Brinell testers, bend, impact, tensile, and ductility testers are some of the products. Bulletin Oy-140.

Bright Annealing

Various types of electric and fuel-fired furnaces built by the Electric Furnace Co. for bright-annealing wire, tubing, strip and other products are described in an 8-page folder. Bulletin Lb-30.

Burner Economy

Interesting photographs and text are used by Surface Combustion Corp. to show that a choice of 47 different types and more than 400 different sizes is sure to give economy in operation. Bulletin Ca-51.

Cadalyte "39"

A new technical service manual on CADALYTE "39" for cadmium plating has been issued by the Electroplating Division of Du Pont. Cites recent improvements and changes in the product, and gives detailed operating instructions and methods of analyses. A table of costs and time required for specified deposits is included. Bulletin Gb-29.

New Machines

The Acme Machinery Company has just published two catalogs, one describing Acme Model XL Threading Machines, the other describing Acme Model XN Forging Machines. Both announce the new Model XR Roll Threading Machine, which rolls threads on bar stock up to 1½-inch diameter in any length. Bulletin Kc-39.

Cinch Steel Cement

How Cinch steel cement saves high speed steel and Stellite by permitting the using up of short pieces is told in a bulletin by Claud S. Gordon Co. Bulletin Ka-53.

Chapmanizing

Chapmanizing, the method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Compressor Data

General information on the application of blowers to gas and oil burners, and miscellaneous applications for other types of work are included in a 12-page "Turbo Compressor Data Book." Useful tables and charts are included. Spencer Turbine Co. Bulletin Dy-70.

Welding Pipe Lines

An improved welding method used in the construction of over 5000 miles of cross-country pipe lines is discussed in a 32-page illustrated booklet published by The Linde Air Products Co. Bulletin Da-63.

Electromet Review

A very attractive house organ which gives news and views of alloy steels and irons, but is mostly concerned with stainless steels. Electro Metallurgical Co. publishes it. Bulletin Ox-16.

Low-Alloy Steel

A new folder on Mayari R, Bethlehem's high-strength, corrosion resisting steel, is colorfully illustrated with views of its various uses. Bulletin Kc-76.

Moly Matrix

Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue—Bulletin Ax-4.

Pressure Blowers

Combustion Air for all industrial applications is discussed in a new folder by the Eclipse Fuel Engineering Co. Bulletin Kc-226.

Electrode Quantities

A handy estimator for determining Arc-Welding electrode quantities is available in attractive form through the General Electric Co. Bulletin Kc-60.

Screw Machining

Screw machine products of aluminum are treated in authoritative and extensive manner in a booklet of Aluminum Co. of America. Besides general data on screw machining, a number of very useful tables appear. Bulletin Ar-54.

High Tensile

The 19 advantages that USS Cor-Ten steel offers to railroads and other industries are attractively presented in a 68-page book on this new low cost, high tensile steel published by United States Steel Corp. Bulletin Ka-79.

Brazing Alloy

Sil-Fos for joining brass, bronze, nickel, nickel silver, extruding brass and bronze, monel metal and other non-ferrous metals and alloys fusing above 1300° F. is a product of Handy & Harman, described in Bulletin Jy-126.

Carburizing Retorts

Low cost, flexibility, uniformity, control, quality, and less labor with retort gas carburizing, says American Gas Furnace Co. Rotary, vertical and bell type retorts are described in Bulletin Jy-11.

Homo Furnaces

The complete line of modern Homo furnaces is shown in a profusely-pictured 36-page catalog issued by Leeds & Northrup Co. Shows many varieties of work now being tempered, annealed or normalized in modern Homo furnaces. Bulletin Fb-46.

Galvanizing

An informative, historical, simple digest of galvanizing forms a guide to longer life for iron and steel products. This handsome, handy, 24-page book beautifully printed in color is distributed by American Hot Dip Galvanizers Association, Inc. Bulletin Ea-167.

Welding Stainless

How to weld stainless steels is described in a colorful 12-page folder released by the Page Steel and Wire Division of American Chain & Cable Co., Inc. Bulletin Cc-86.

Carburizing Baths

Interesting savings in Case Hardening Baths are shown in a new folder which explains the Holden line of carburizing baths just published by A. F. Holden Co. Bulletin Kc-55.

New Heat Source

The New Source of Heat for Heat Treating, Brazing and Melting of ferrous and non-ferrous metals is described in an attractive booklet by Lepel High Frequency Laboratories, Inc. Bulletin Kc-211.

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Lectrodryer

A machine designed specifically for the dehumidification of air and other gases as well as certain liquids—the "Lectrodryer"—is pictured and explained in a booklet by the Pittsburgh Lectrodryer Corp. Bulletin Gc-187.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Electric Furnaces

A new catalog on electric furnaces and pyrometers has been released by the Hoskins Manufacturing Company. For anyone who does any kind of heat-treating, brazing, or uses heat-resisting castings. Bulletin Hc-24.

Hardened Gearing

Extremely valuable technical information on heat treated hardened gearing, including treatment, control and quenching, comparison of properties, etc., is included in a booklet by the Westinghouse Electric & Mfg. Co. Bulletin Hc-134.

Pure Metals

Pure, carbide-free metals are described and applications suggested in a pamphlet published by Metal & Thermit Corp., who make pure tungsten, chromium and manganese in addition to the ferro-alloys. Bulletin Ma-64.

Heat Treat Chart

Heat treaters everywhere should find a heat treating wall chart complete with S.A.E. specifications a very valuable addition to their shops. Published by Chicago Flexible Shaft Co., manufacturers of Stewart industrial furnaces. Bulletin Ka-49.

Metalwove Belts

Metalwove Belts used in a wide range of applications heretofore believed impractical in the continuous treatment of metals are illustrated and described in a new catalog released by Audubon Wire Cloth Corp. Bulletin Kc-250.

Tool Steels

A new bulletin describing the standard grades of SKF tool steel as well as forging and heat treatment recommendations is available through SKF Steels, Inc. Bulletin Kc-78.

HELPFUL LITERATURE

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-169.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc., giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Carburizing Salt

A technical service bulletin describing a new development—Du Pont Carburizing Salt—for the economical production of deep high-carbon cases on plain carbon and alloy carburizing steels . . . available through DuPont. Bulletin Dc-29.

Portable Hardness Tester

The "Telebrineller" is described in a new bulletin as a simple, rugged, flexible instrument that accurately determines Brinell hardness of surfaces and objects inaccessible to conventional testers. Total weight, 6½ lbs. Teleweld, Inc. Bulletin Dc-98.

Oil Burners

North American Mfg. Co. offers a bulletin describing improved low pressure oil burners, one type especially designed for automatic control and ideally suited for use with proportioning control valves. Bulletin Na-138.

Hydryzing

Hydryzed work is completely described in recent literature released by Lindberg Engineering Co. Points out advantages in particular applications. Bulletin Bc-66.

Heat Treating Furnaces

A brand new 16-page booklet of Holcroft & Company shows and describes their line of controlled atmosphere heat treating furnaces. Bulletin Ec-203.

Testing Metal Sheets

The Drawing, Stamping, Compressing and Folding Qualities of Sheets, thickness from 0.1 to 3 millimeters, can be determined quickly and easily with the standard Erichsen Machine described in a bulletin by the Bock Machine Co. Bulletin Kc-252.

Tool Steels

Information about the fine steels made by the Uddeholm Company of America, Inc., can be obtained by requesting their new bulletin. This company controls its output completely from the ore mine to the consumer. Bulletin Eb-196.

Dust Control

Dust control in the plant is as important as dust control on the prairies. American Foundry Equipment Co. points out in a booklet describing their "Dustube" dust collectors. Bulletin Id-112.

Bessemer Steel

Jones & Laughlin Steel Corp. has for distribution reprints of the paper by C. C. Henning on "Manufacture and Properties of Bessemer Steel" that received the Robert W. Hunt Award of the A.I.M.E. Bulletin Ca-50.

More Dust Hog

Those who have been following the Dust Hog series of the Pangborn Corp. which analyzes the cost of dust to industry, will appreciate the fifth and sixth folders of the series which are now available. Bulletin Lc-68.

Direct Reading Brinell

Production testing on parts of any shape without spotting or the use of a microscope is possible through the new Direct Reading Brinell machine described in a folder by the Detroit Testing Machine Co. Bulletin Gc-245.

Cr-Ni-Mo Steels

A. Finkl & Sons' new catalog is really a technical treatise on chromium-nickel-molybdenum steels for forgings. Pocket size, 104 pages, cloth bound, illustrated by photographs, charts and tables. Bulletin La-23.

Contour Metal Shaping

A very colorful, plastic-bound booklet containing Job Sheets on metal shaping jobs will be helpful to men in Shipbuilding, Plastics, Silverware, and Automotive fields. Available through Continental Machines, Inc. Bulletin Lc-170.

Metallographic Reference

Nearly one thousand technical books and reference papers on Optical Principles in Metallography are listed in the new Metal Analyst just released by Adolph I. Buehler. Bulletin Lc-135.

Recording Control Equipment

Now available from Baldwin-Southwark Corp. is a new 16-page bulletin illustrating and describing Southwark's complete line of stress-strain recorders and extensometers. Bulletin Bc-67.

Micro-Optical Pyrometers

A new instrument which permits measuring the temperatures of very small objects such as incandescent lamp filaments, etc., and for laboratory and scientific research work has been developed by the Pyrometer Instrument Co. Bulletin Kc-37.

Heroult Furnace

Revised and expanded to include modern major innovations in the construction and operation of the Heroult electric furnace, the latest edition of the American Bridge Co.'s Heroult Electric Furnace Bulletin is available. Bulletin Bb-124.

Seamless Tubes

Prepared by the Timken Steel and Tube Division of Timken Roller Bearing Co. is a "Guide for Users of High Temperature Steels," which presents technical data relating to the various properties of Timken seamless tubes. Bulletin Bb-71.

Wide-Strip Pyrometer

Complete information on the new Bristol Multiple Record Wide-Strip Pyrometer can be obtained through the Bristol Company. Gives up to 8 temperature records on the same chart. Bulletin Ac-87.

Colmonoy

The high resistance to wear and corrosion which distinguishes Colmonoy alloys and overlay metals is explained in a 4-page catalog released by Wall-Colmonoy Corp. Bulletin Bc-85.

Tellurium Coppers

A comparison of Chase Tellurium Coppers with other alloys is contained in a new folder published by the Chase Brass & Copper Co. Bulletin Kc-59.

Annual Index

The Annual Index of the Copper Alloy Bulletin published regularly by the Bridgeport Brass Company is now made available through this company. Bulletin Kc-163.

Steel Stock List

Ryerson "Certified" Steels are listed in an attractive stock list just made available by Joseph T. Ryerson & Son, Inc. Bulletin Kc-106.

Core Baking Ovens

Helpful facts for producing better cores for the foundry are contained in an attractive 8-page folder printed by The Paul Maehler Co. Bulletin Kc-159.

Industrial Furnaces

The Rockwell Furnace line, developed over half a century, is described in an attractive folder released by W. S. Rockwell Co. Bulletin Kc-34.

Ni-Cr Castings

Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Mo-W High Speed

J. V. Emmons, metallurgist for Cleveland Twist Drill Co. and largely responsible for the development of the molybdenum-tungsten high speed steels known as Mo-Max, has prepared a general description of these new steels. Bulletin Ka-103.

Gas Carburizing

"Three methods of gas carburizing," a reprint of an article by W. A. Darrah, Pres., Continental Industrial Engineers, Inc., is available for those interested in this subject. Bulletin Kc-154.

Hardness Testing

A 4-page folder which has as its purpose "to give you an idea of how practical a thing it is to make hardness tests on raw stock or fabricated metal parts in all plants where metal is worked, and to suggest something of the necessity for making such tests, or at least their importance" is available through the Wilson Mechanical Instrument Co., Inc. Bulletin Fb-22.

Lubrication

Intensive research which completed important improvements in the field of heavy-duty gear and bearing lubrication is tabulated in a new 12-page illustrated bulletin just released by D. A. Stuart Oil Co., Ltd. Bulletin Lb-118.

Globar Elements

Globar Pin Type Non-Metallic Electric Heating Elements and Terminal Rods and Globar "AT" Type Non-Metallic Electric Heating Elements are explained and illustrated in two recent booklets issued by the Globar Division of the Carborundum Company. Bulletin Lb-25.

Spring Making Machines

New, improved Spring Coiling Machines are described and shown in bulletins covering a complete range of Segment and Clutch Type Coilers and Torsion Spring Winders. The Torrington Mfg. Co. Bulletin Kc-251.

HELPFUL LITERATURE

Thermometers

A new line of thermometers and pressure gauges is announced in a colorful 8-page booklet by the Brown Instrument Co. Bulletin Lc-3.

Cutting Oils

An interesting new booklet "Metal Cutting Lubrication—In Theory and Practice" has just been made available by Cities Service Oil Co. Bulletin Ec-113.

Foundry Sand

A pamphlet recently issued on TAM Foundry Zircon Sand and TAM Zircon Flour contains detailed information on these products of the Titanium Alloy Mfg. Co. Bulletin Hc-90.

Tremendous Trifles

Another of International Nickel's instructive folders on Monel Metal covering actual case studies of the use of Monel is now available. Bulletin Lc-45.

Controlled Combustion

Direct Fired Air Heaters which make possible Controlled Combustion and permit wider range in oven and furnace operation are explained in a 4-page folder by the Despatch Oven Co. Bulletin Lc-123.

Optical Pyrometer

The first industrial Optical Pyrometer to use the potentiometer method of measurement is featured in an interesting and instructive booklet published by Leeds & Northrup Co. Bulletin Lc-46.

Machining Data

A new chart giving the correct grade of Kennametal for machining 21 types of metals, with recommended cutting speeds, has just been made available by McKenna Metals Co. Bulletin Lc-238.

Permanent Magnet Steels

The new issue of Simonds booklet on "Permanent Magnet Steels and Castings" is now available. Bulletin Kc-158.

Burners

New and up-to-date bulletins by Eclipse Fuel Engineering Co. covering many types of burners as well as their complete listing of products are now available. Bulletin Lc-226.

Tool Steels

Matched tool steels are explained in a brand new 60-page manual just made available by the Carpenter Steel Co. Interesting savings explained. Bulletin Lc-12.

Tocco Process

The marvel of all heat treaters—the Tocco Process of Induction Hardening—is fully described in a colorful folder by the Ohio Crankshaft Co. Bulletin Lc-145.

Potentiometer Controller

A series of controllers adapted to actuate any customary type of fuel valve or electric contactor is described in a bulletin by Wheelco Instrument Co. Bulletin Lc-110.

Welding Ideas

Illustrating and describing a wide variety of money-saving repair, fabrication and structural applications of arc welding, a new bulletin "101 Welding Ideas for Low Cost Maintenance" is available through the Lincoln Electric Co. Bulletin Kc-10.

Arc Welders

The three types of Marquette a.c. arc welders, in ranges up to 250 amps., are illustrated and described in this folder. The machines feature streamlined design and 15 taps on the front panel which provide a wide choice of welding amperage. Marquette Mfg. Co., Inc., Minneapolis. Bulletin Ec-216.

Heat Resisting Castings

A 4-page folder on Pyrasteel, heat resisting castings, that shows applications of special alloy steels and their analyses, also information on welding alloy steels, is available through Chicago Steel Foundry Co. Bulletin Cb-184.

Insulation

A 32-page catalog containing specific information on all of the sheet, block and pipe insulations developed by the Johns-Manville Company is now available through that company. Bulletin Fb-100.

Lectromelt Furnaces

The story behind lectromelt furnaces is well told in this 48-page booklet issued by the Pittsburgh Lectromelt Furnace Corporation. Tells of development and recent improvements. Bulletin Db-18.

Ampco Data

An interesting bound volume of Ampco Engineering Data Sheets which give performance records and details about the six grades of Ampco Metal is now available. Bulletin Fc-175.

Copper

OFHC Copper conforming to the A.S.T.M. specifications for electrolytic copper wirebars, cakes, etc., is described in literature made available through the Scomet Engineering Co. Bulletin Kb-209(a).

Model "Y"

The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment, provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

Hydrogen Brazing

A new "Electroblast" hydrogen brazing furnace designed for the inexpensive, clean brazing of carbide-tipped tools is described in a folder by Stark Tool Co. A full description of the method of brazing and precautions necessary is included. Bulletin Ab-186.

Multi-Point Pyrometer

The Alnor Rectangular Type Pyrometer, designed to provide a rugged moderately priced instrument with multi-point switch, is described in a release by the Illinois Testing Laboratories, Inc. Bulletin Dc-180.

Vanadium Steel

Latrobe Electrite Vanadium High Speed Tool Steel is described in literature released by the Latrobe Electric Steel Co. Bulletin Kb-208.

Prevention of Rust

"Proof of Results" is the apt title of a new booklet issued by Dearborn Chemical Co. Dozens of photographs, supported by an interesting text, show how No-Ox-Id keeps steel from rusting. Bulletin Mr-36.

Stainless Steel Stock List

A handy 16-page Stocklist showing size of Rezistal sheets, bars and welding rods carried in Crucible's Mills and 26 branches is offered by the Crucible Steel Company of America. Bulletin Kc-56.

Electric Furnaces

An 8-page booklet on high frequency heating for forging, hardening, brazing, etc., with general description of equipment has been issued by the Ajax Electrothermic Corp. Bulletin Kc-41.

Lubricant Economy

Extreme pressure treated, high film strength lubricants, known as Houghton's Sta-Put series, grouped and graded according to industrial machinery applications, are described in a well-illustrated booklet entitled "Less Oil—Less Often." E. F. Houghton & Co. Bulletin Ab-38.

Metal Hydrides

Reprints of articles by Dr. P. P. Alexander on "The Hydride Process" discuss history, production and the uses of metal hydrides. Metal Hydrides, Inc. Bulletin Db-190.

Boxes and Trays

Standard Alloy Co. offers all those advantages which spring from long specialization in heat and corrosion resisting alloy castings for such things as boxes and trays. An abundance of proven data is contained in Bulletin Oy-151.

Firestone

A story of the origin and history of Buckeye silica firestone makes an interesting preamble to a complete technical discussion of the properties and applications of this refractory. Cleveland Quarries Co. Bulletin Ka-176.

Ledloy

A new cold drawn steel developed by Wyckoff Drawn Steel Company under the name of "Ledloy" is described in a bulletin just issued. Available in all standard S.A.E. analyses, this steel has interesting advantages. Bulletin Kb-99.

Gases for Bright Annealing

Bulletin gives details concerning the Industrial Carburetor, heart of the Atmos-Gas producer, shows types of installations and gives useful tables. C. M. Kemp Mfg. Co. Bulletin Ec-219.

High Temperature Combustion Furnaces

Single and double tube laboratory furnaces, provided with Globar elements producing temperatures up to 2500° F., are described in a bulletin of Burrell Technical Supply Co. Bulletin Ec-213.

Carburizing Compounds

Aerocarb Carburizing Compounds, the new development of the American Cyanamid & Chemical Corp., are described in Bulletin Dc-148.

Doall Digest

The "Doall Digest" is a little periodical issued by Continental Machines, Inc., containing interesting information on a wide range of machining operations possible with Doall equipment. Get the latest issue by asking for Bulletin Id-170.

Instruments Range

From molten metal to motor cars—a folder by Foxboro Co. graphically illustrates the wide range of applications for Foxboro instruments in all production and processing operations. Bulletin Id-21.

Salt Bath Furnace

A colorful 12-page illustrated booklet describing the new Ajax Hultgren Electric Salt Bath Furnace has been released by the Ajax Electric Co. Bulletin Ec-43.

High Temperature Insulation

An illustrated leaflet is devoted to types and uses of thermal insulation, for all types of heating equipment. Armstrong Cork Products Co. Bulletin Ec-221.

Welding Procedures

Procedures for producing all types of welds in mild steel, for welding all metals used to any extent industrially and for applying surfacing metal to meet any type of wear-action in service . . . in a booklet by The Lincoln Electric Co. Bulletin Bc-10.

Instruments

A new general catalog including machine tools, instruments and machinery made by George Scherr Co. contains several items being shown in the U.S. for the first time. Bulletin Ec-206.

Alloy Castings

Calite Chromium-nickel alloy castings for furnace roller rails are pictured and described in a release by the Calorizing Co. Bulletin Ec-26.

Super Refractories

A catalog of Chas Taylor Sons Co. is replete with useful data on P. B. Sillimanite refractories for use up to 3000° F. in electric furnace roofs and linings, induction furnaces, crucible furnaces, fuel-fired hearths, piers and linings, burner blocks, etc. Bulletin Ec-218.

New Copper Alloy

Mallory 333 metal, a new copper-chromium-lithium alloy, described as combining hardness with high conductivity, is useful for welding electrodes and other applications, according to a bulletin of P. R. Mallory & Co. Bulletin Ec-220.

New High-Strength Steel

This little book gives facts and figures on DYN-EL, a new high strength, flat rolled steel claimed to have unusual resistance to fatigue, impact and corrosion. Complete fabricating and design properties and table of sizes and weights are included. Alan Wood Steel Co. Bulletin Ec-225.

Duriron

A new bulletin on steam jets, ejectors, tank outlets and spray nozzles has just been issued by the Duriron Co. Illustrated with photographs and dimension drawings of the equipment. Bulletin Gc-152.

Refining Slag

Purite made by Mathieson Alkali Works is stated to reduce metal shrinkage and casting losses and to improve general quality by forming a protecting and refining slag. Composition, general instructions for use, and directions for use with various furnaces are given in Bulletin Ec-224.

Strenes Metal

A colorful folder gives the story of Strenes Metal, a new and unique material that is a chromium-nickel-molybdenum alloy with a high steel base, used primarily for cast-to-shape forming and drawing dies. Advance Foundry Co. Bulletin Ec-231.

Bimetal

Interesting facts about thermostatic bimetal are contained in an extremely well-prepared book by W. M. Chace Valve Co. Applications, forms available, and how the material acts in temperature control devices are given. Bulletin Ec-232.

Immersion Heaters

Bulletin on how to heat electroplating baths with General Electric immersion heaters includes information on what heat does, how much heat to use, and how to determine current requirements, as well as catalog numbers, prices and discounts on electric heating equipment. Bulletin Id-60.

Burners for Industrial Furnaces

This illustrated, 4-page folder is devoted to the new Duradiant burner whose outstanding feature is a refractory burner tip. Chamber temperatures from 3000 to 2400° F. can be produced. Selas Company. Bulletin Ec-214.

Plastic Testing

Modern plastic material testing machines have been completed by Tinius Olsen Testing Machine Co. and are described in a colorful booklet just released. Bulletin Ec-147.

Dowmetal Data Book

A new edition, containing especially significant accomplishments in the sections of "Available Forms" and "Shop Practice" has been published by Dow Chemical Co., Dowmetal Div. Bulletin Ec-215.

Furnace Experience

Facts developed through 32 years of engineering and building practically every type of industrial fuel equipment can be obtained through Flinn & Dreffein Co. Bulletin Bc-82.

Heat Resisting Castings

A 4-page folder on Pyrasteel, heat resisting castings, that shows applications of special alloy steels and their analyses, also information on welding alloy steels, is available through Chicago Steel Foundry Co. Bulletin Cb-184.

Vanadium Castings

A 24-page bulletin well illustrated with more than 20 photographs contains a complete description of the properties and applications of a number of vanadium alloy steels for castings where high strength is required without excessive weight or high cost. Vanadium Corp. of America. Bulletin La-27.

Stainless Electrodes

An attractive 16-page booklet printed in aluminum contains interesting facts about stainless electrodes, with particular attention to McKay "Certified" electrodes. The McKay Co. Bulletin Hc-248.

Ground Shafting

A colorful folder describing Ground Shafting made by Bliss & Laughlin, Inc., is now available through this company. Pictures steps in shafting production. Bulletin Bc-42.

Metal Powders

An attractive booklet containing analyses of metal powders and screen sizes is published by Metals Disintegrating Co. Bulletin Ec-208a.

Architectural Shapes

Amply illustrated by excellent photographs and drawings of extruded architectural shapes, a very well made up bulletin on copper, brass, bronze and nickel silver architectural shapes and sheets is available from Revere Copper and Brass, Inc. Bulletin Id-239.

Degreaser

Degreasing machines for practically every cleaning job are described in literature made available through the Detroit Rex Products Company. Bulletin Hc-111.

Crucible Furnaces

A new bulletin on multiple unit crucible furnaces and Hevi Duty crucible furnaces has been released by the Hevi Duty Electric Co. Bulletin Hc-44.

Una Taper

An amazing new machine for automatic protected arc welding has been developed by Una Welding, Inc. Details will be furnished on writing for Bulletin Kb-207(a).

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STATEMENT OF THE OWNERSHIP, MANAGEMENT, CIRCULATION, ETC.

Required by the Acts of Congress of August 24, 1912, and March 3, 1933, of **Metal Progress,** published monthly at Cleveland, Ohio, for October 1, 1939.

State of Ohio } ss.
County of Cuyahoga }

Before me, a Notary Public in and for the State and county aforesaid, personally appeared Ray T. Bayless, who, having been duly sworn according to law, deposes and says that he is the business manager of **Metal Progress** and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management, etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, as amended by the Act of March 3, 1933, embodied in section 537, Postal Laws and Regulations, to wit:

1. That the names and addresses of the publisher, editor, managing editor, and business manager are: Publisher, American Society for Metals, 7016 Euclid Ave., Cleveland, Ohio; Editor, E. E. Thum, 7016 Euclid Ave., Cleveland, Ohio; Managing Editor, E. E. Thum, 7016 Euclid Ave., Cleveland, Ohio; Business Manager, Ray T. Bayless, 7016 Euclid Ave., Cleveland, Ohio.
2. That the owner is: The American Society for Metals, 7016 Euclid Ave., Cleveland, Ohio, which is an educational institution, the officers being, President, James P. Gill; Vice-President, Oscar E. Harder; Secretary, W. H. Eisenman; Treasurer, Kent R. Van Horn; Trustees: D. S. Clark, F. B. Foley, H. J. French, M. A. Grossmann, W. P. Woodside. All officers as above, address 7016 Euclid Ave., Cleveland, Ohio.
3. That the known bondholders, mortgagees, and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages, or other securities are: None.
4. That the two paragraphs next above, giving the names of the owners, stockholders, and security holders, if any, contain not only the list of stockholders and security holders as they appear upon the books of the company but also, in cases where the stockholder or security holder appears upon the books of the company as trustee or in any other fiduciary relation, the name of the person or corporation for whom such trustee is acting, is given; also that the said two paragraphs contain statements embracing affiant's full knowledge and belief as to the circumstances and conditions under which stockholders and security holders who do not appear upon the books of the company as trustees, hold stock and securities in a capacity other than that of a bona fide owner; and this affiant has no reason to believe that any other person, association, or corporation has any interest direct or indirect in the said stock, bonds, or other securities than as so stated by him.

Ray T. Bayless,
Business Manager.

(Seal)

Sworn to and subscribed before me this 2nd day of October, 1939.

Arthur T. Wehrle,
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(My commission expires Jan. 20, 1941)

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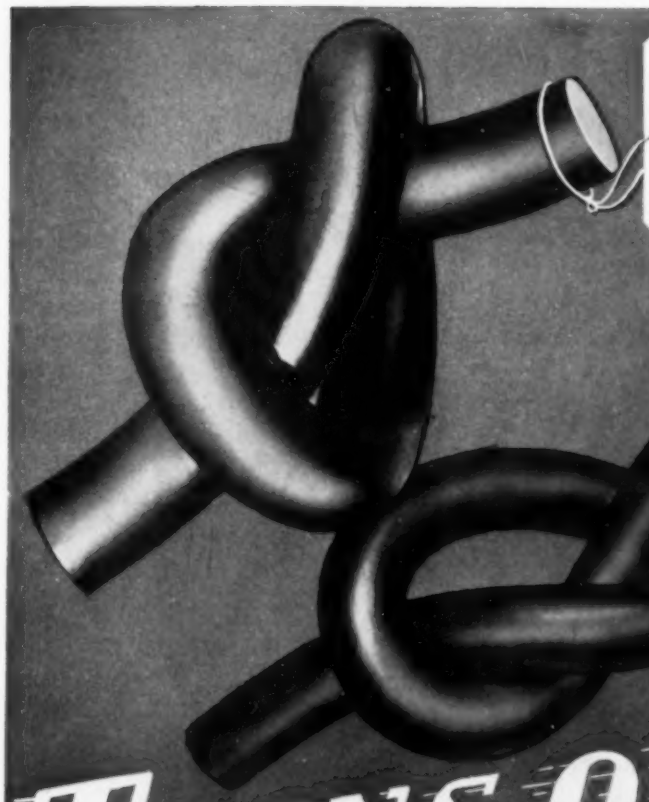

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Machining copper

(Continued from page 635)

20°. High speed tools are much to be preferred over carbon steels. Tools tipped with tungsten carbide or stellite are exceptionally resistant to abrasion, and can be used without coolant at extremely high speeds on all copper alloys.

Group A materials in cast form machine somewhat "shorter" than the corresponding wrought materials, probably because their structure is interspersed with minute shrinkage cavities and gas pockets.

Group B, duplex alloys, includes the alpha-beta brasses, manganese bronzes or brasses, duplex aluminum bronzes, nickel brasses, cast phosphor bronzes and silicon bronzes and gun metals. Their machining properties differ from those of Group A, owing to the fact that they can withstand much less plastic deformation when cold. Pressure between tool and chip causes shear rather than plastic upset, although some plastic deformation also takes place. The shavings produced, though they may appear outwardly continuous, are structurally discontinuous, presenting a saw-toothed appearance on their inner curl. Such shavings are quite brittle, particularly if bent inside out. With the alloys of high ductility short chips are generally obtained only with coarse feeds; with light feeds closely coiled helical turnings are produced. Being relatively brittle, they can readily be broken up by chip breakers. With alloys of low ductility, such as phosphor bronze, the turnings or chips break up of their own accord into short pieces equal to one turn of the helix, more or less.

This unavoidable shearing slip causes rapid vibration in tool and work, leading to chatter, especially with alloys of low ductility. Chatter in actual machining operations is largely determined by the rigidity of the tool and work, the size of the cut and the design of the tool. Rigidity is of particular importance with the high tensile brasses and bronzes, and heavy cuts require tools and tool holders of substantial dimensions; overhang of tools must be restricted and the work strongly supported.

Since the plasticity of duplex materials is limited, they do not need to be machined with steeply raked tools; indeed, steep top rakes are undesirable, since they cause the tool to feed *into* the work, and thus promote chatter. High speed lathe tools may have a top rake of 8 to 12°; forming tools, 5 to 10°; drills, 10 to 30°; taps, 12°±; milling cutters, 5 to 10°; and dies, 25° max.

(Continued on page 680)

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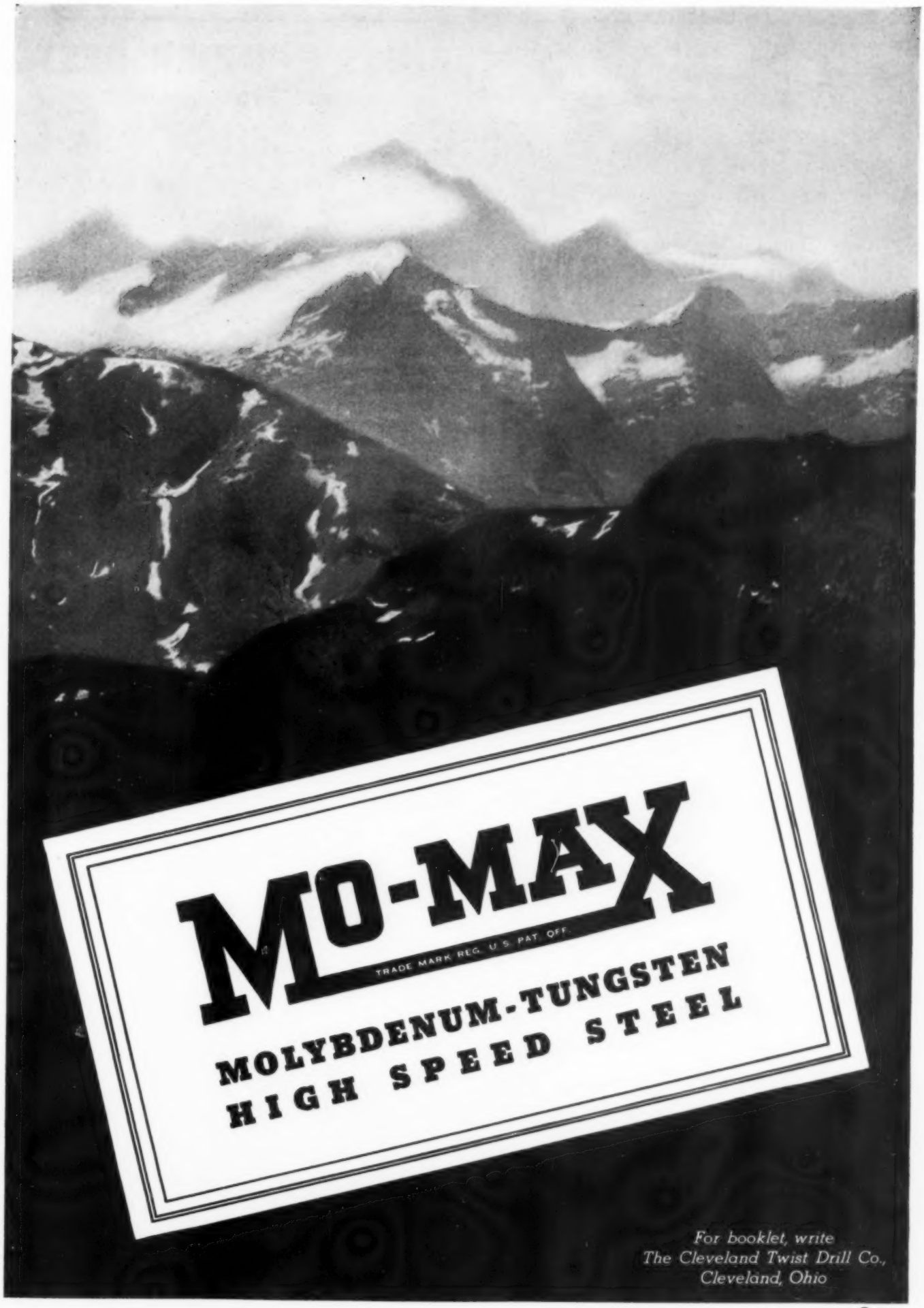
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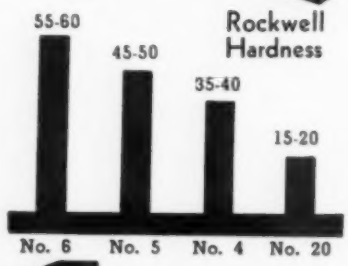

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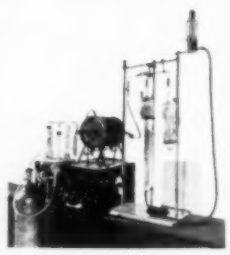

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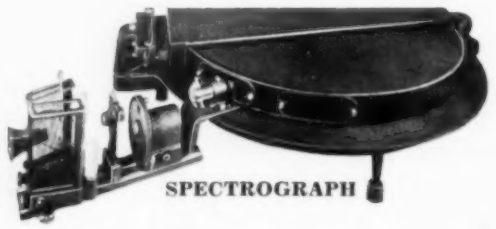

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Machining copper

(Starts on page 635)

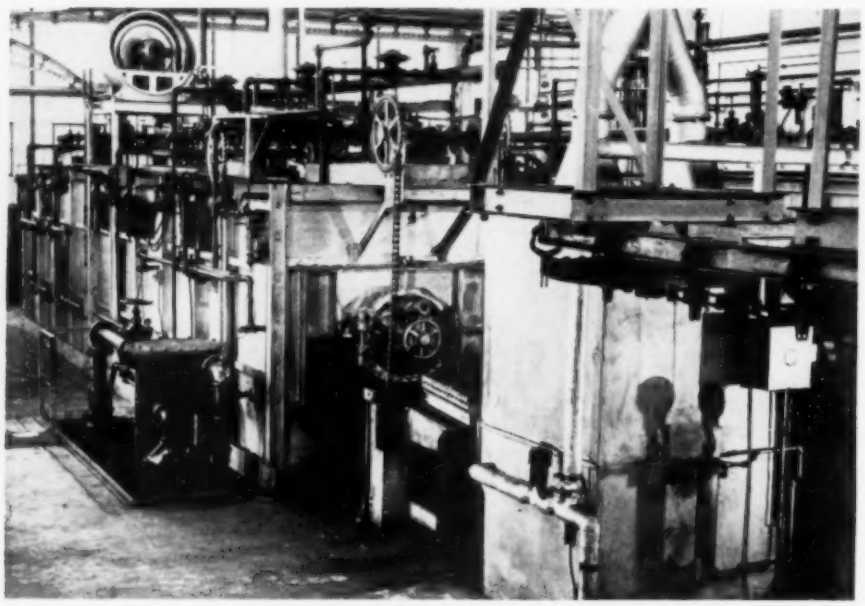
Standard clearances are normally fully adequate.

Provided due regard is given to the above considerations, the duplex brasses and bronzes can be machined much more readily than ferrous materials of equivalent strength and toughness.

Group C may be called "leaded alloys", although other substances than lead have been added to both Group A and Group B alloys to improve machinability. The shearing action on the chips of Group C is completely efficacious, and they break into fine needle-like fragments, which have undergone little or no plastic deformation. The pressure which builds up on the tool face prior to the shearing of each fragment causes both the tool and work to deflect and the tool springs back on the release of this pressure, catapulting the chip a considerable distance from the cutting zone. This spring also tends to produce chatter which is more severe with a leaded alloy than with a lead-free alloy of equivalent tensile strength, because with the latter the release of pressure is only partial, whereas with the leaded alloys, though the average tool pressure is usually lower, the variation is wider.

Since very little plastic deformation occurs and the chips are only in momentary contact with the tool face, there is no risk of tools becoming overheated even where heavy cuts are taken dry at high cutting speeds. Chip friction is almost negligible; burnishing friction along the tool flank just below the cutting edge is the cause of tool failure. Experiments at cutting speeds up to 500 ft. per min. show that the principal factor determining life between grinds is the linear distance travelled by the cutting edge in contact with the work surface. This implies that the tool life is practically independent of cutting speed.

Leaded alloys are usually machined with tools ground with a top rake angle of less than 8°. The function of the tool face is to push or shear off chips from the stock; if relatively flat-topped tools are used, the cutting edge is relieved of much of the force required for this purpose, and the chips are thrown clear of the cutting zone; moreover, the use of steeply raked tools tends to produce digging-in and chatter — at any rate, in roughing operations. With light cuts, however, the finish is generally improved if somewhat steeper rakes are used. Thus, top-rake angles up to 12° may be employed for finishing cuts as, for example, in single-point boring operations on leaded bearing bronzes.



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